



Flux Pinned Interface for Orbiting Sample Capture



**Team Debrief of Flight
Campaign 1
April 13, 2017**

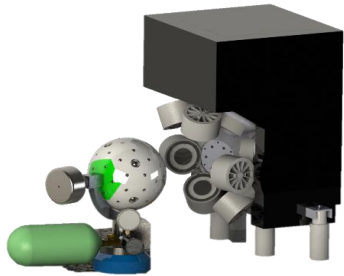
Laura Jones-Wilson,
Jet Propulsion Laboratory,
California Institute of Technology

Joe Parrish,
Jet Propulsion Laboratory,
California Institute of Technology

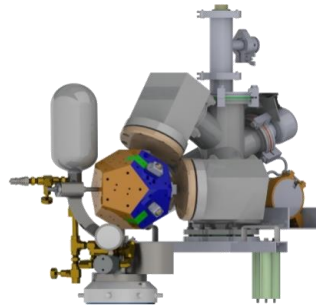
Mason Peck
Cornell University



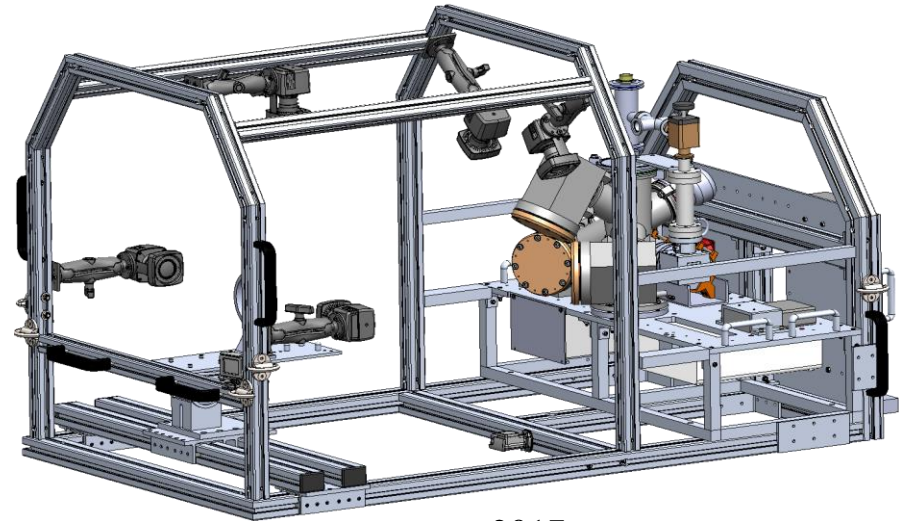
R&TD Evolution



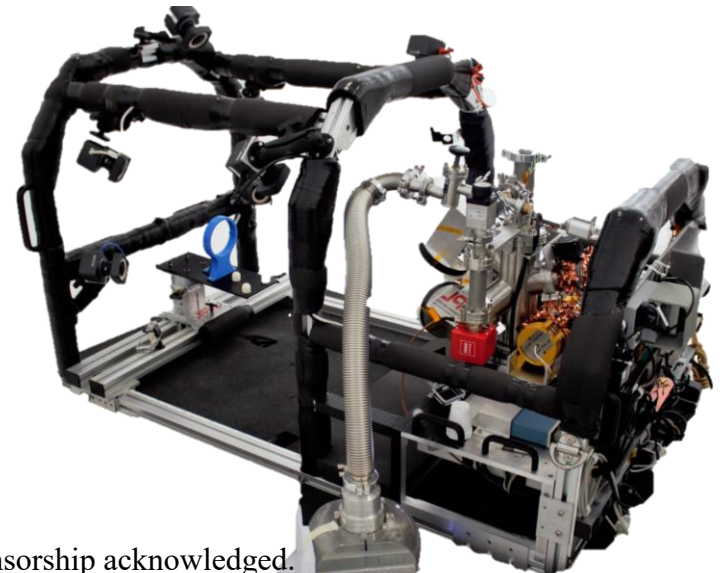
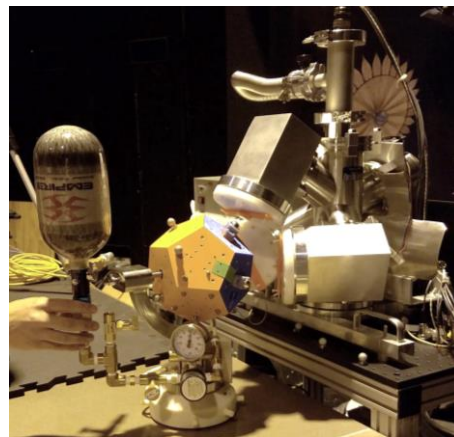
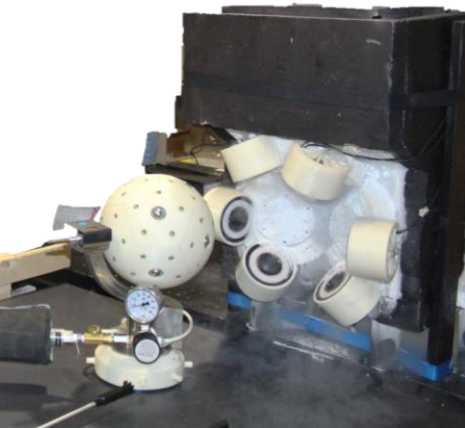
2015
4DOF Air Bearing
LN2 Cooling System



2016
4DOF Air Bearing
Cryocooler Cooling System

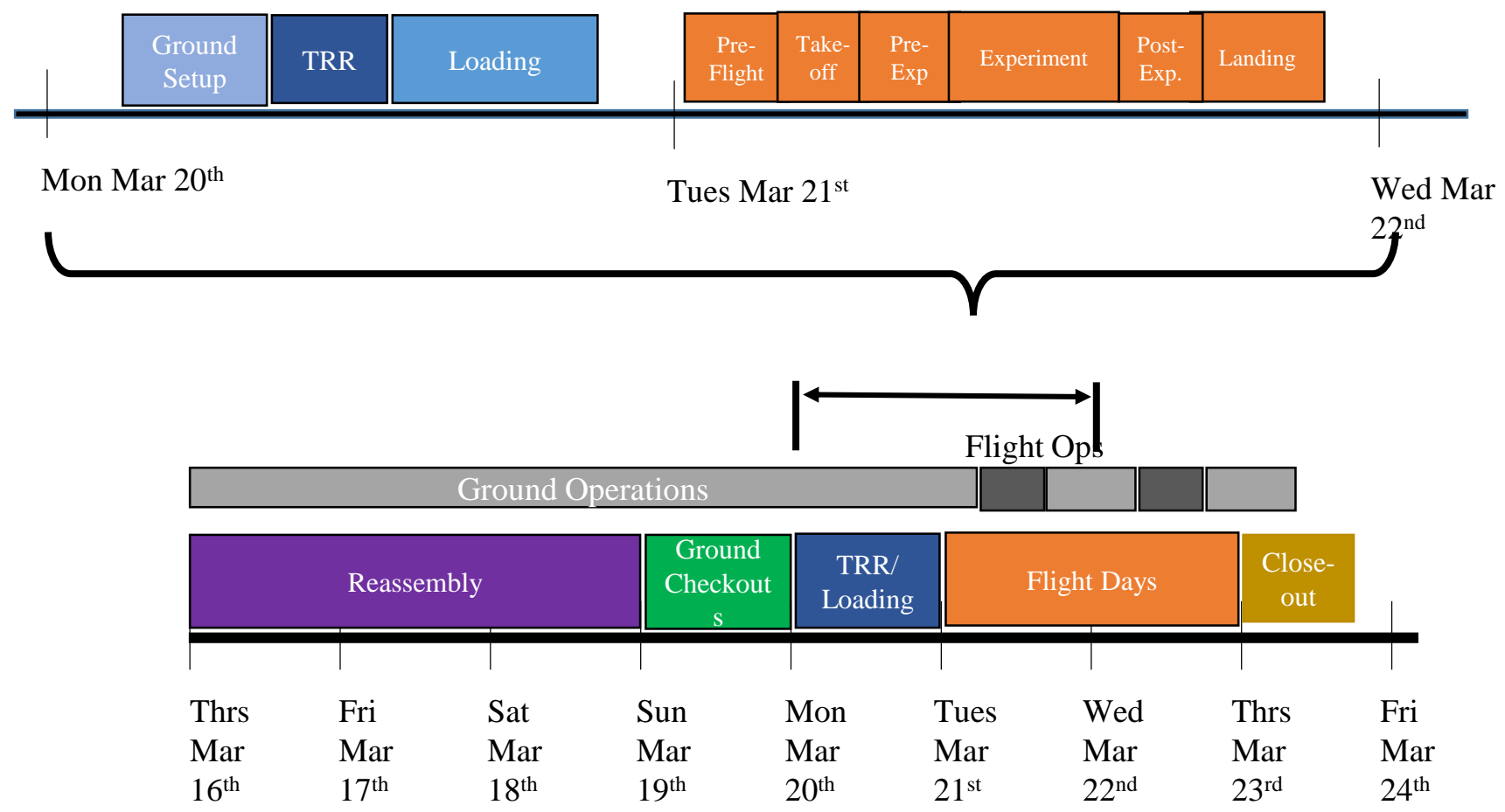


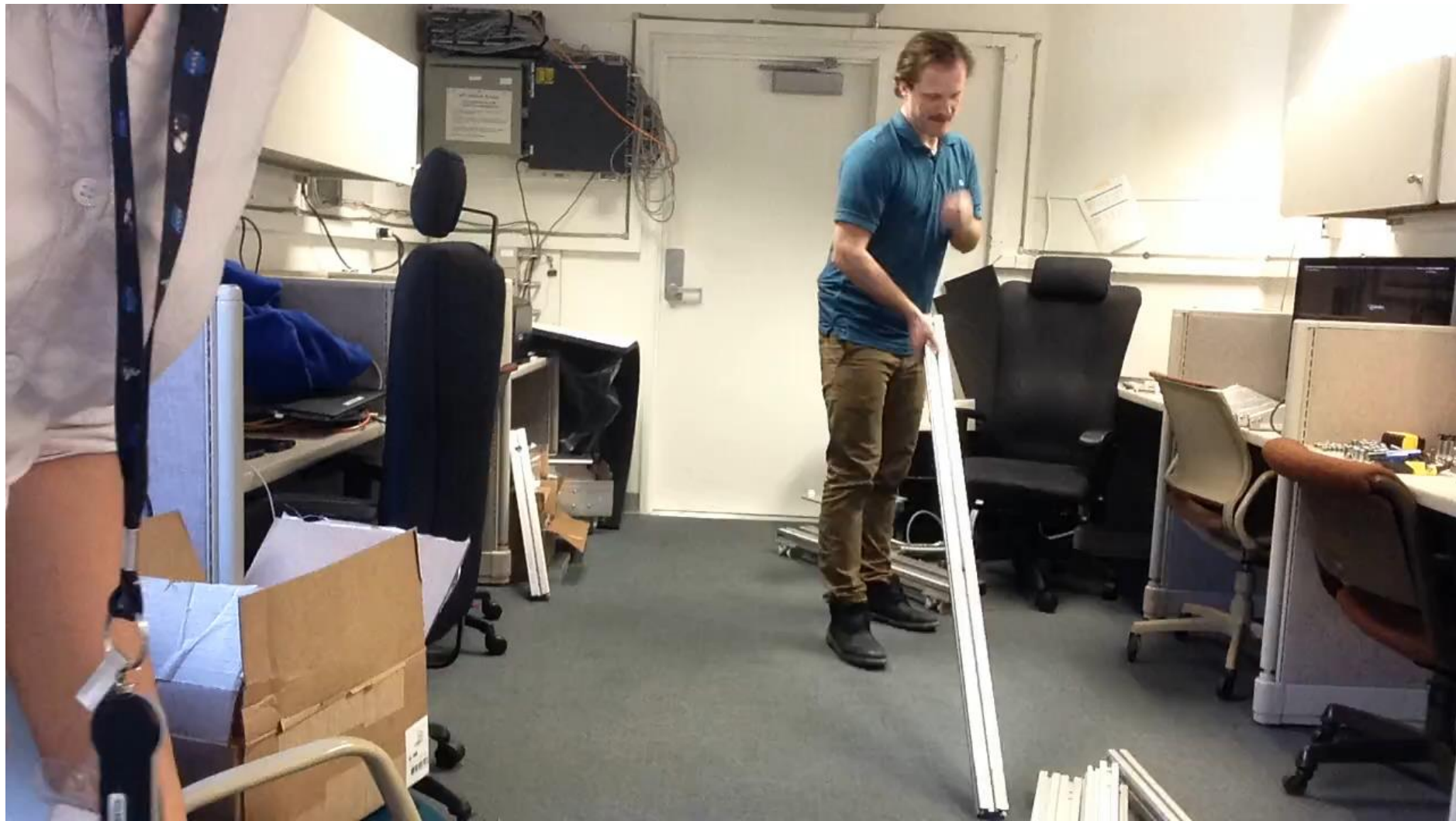
2017
6DOF Microgravity Flight
Cryocooler Cooling System





Timeline





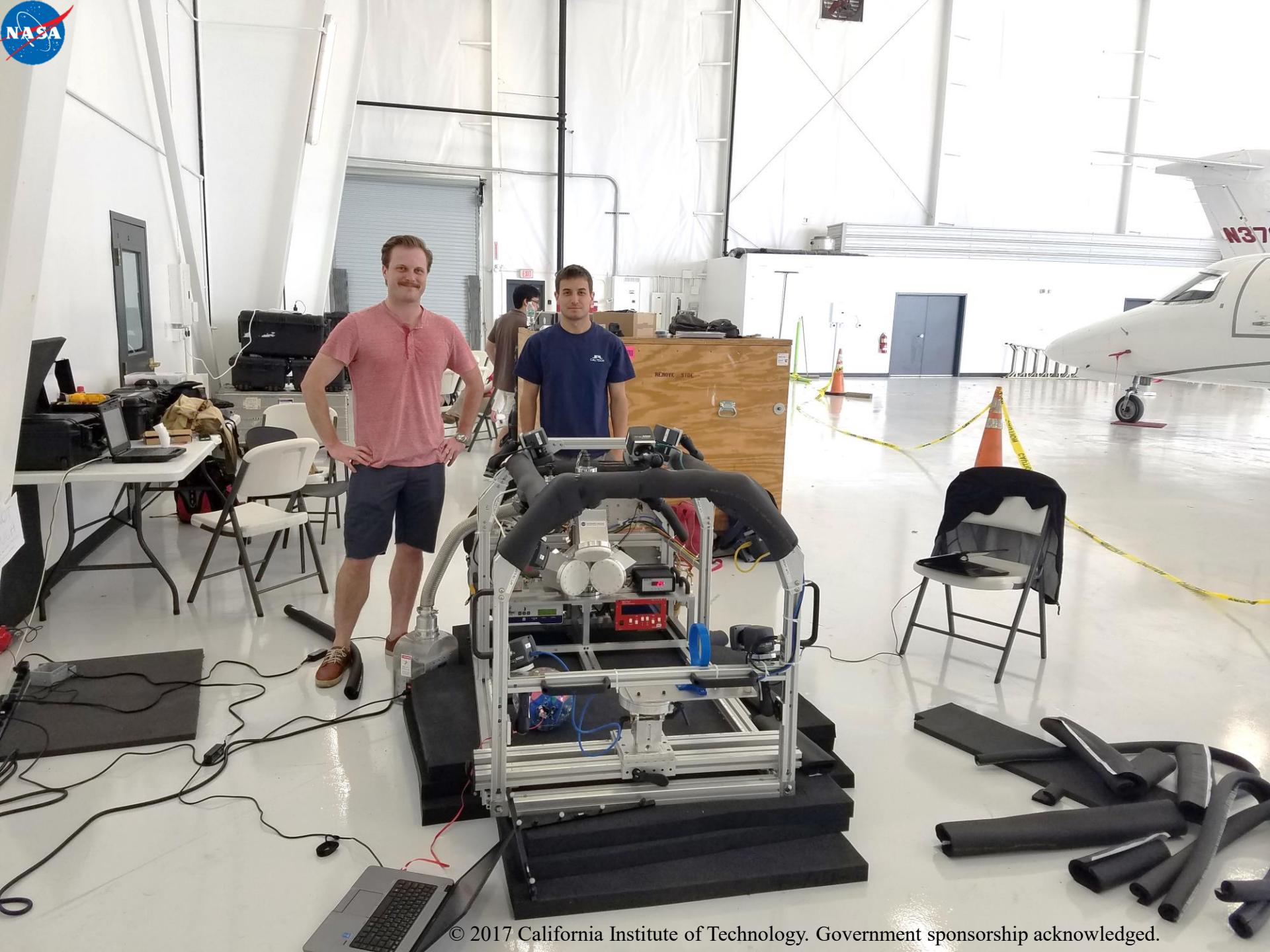


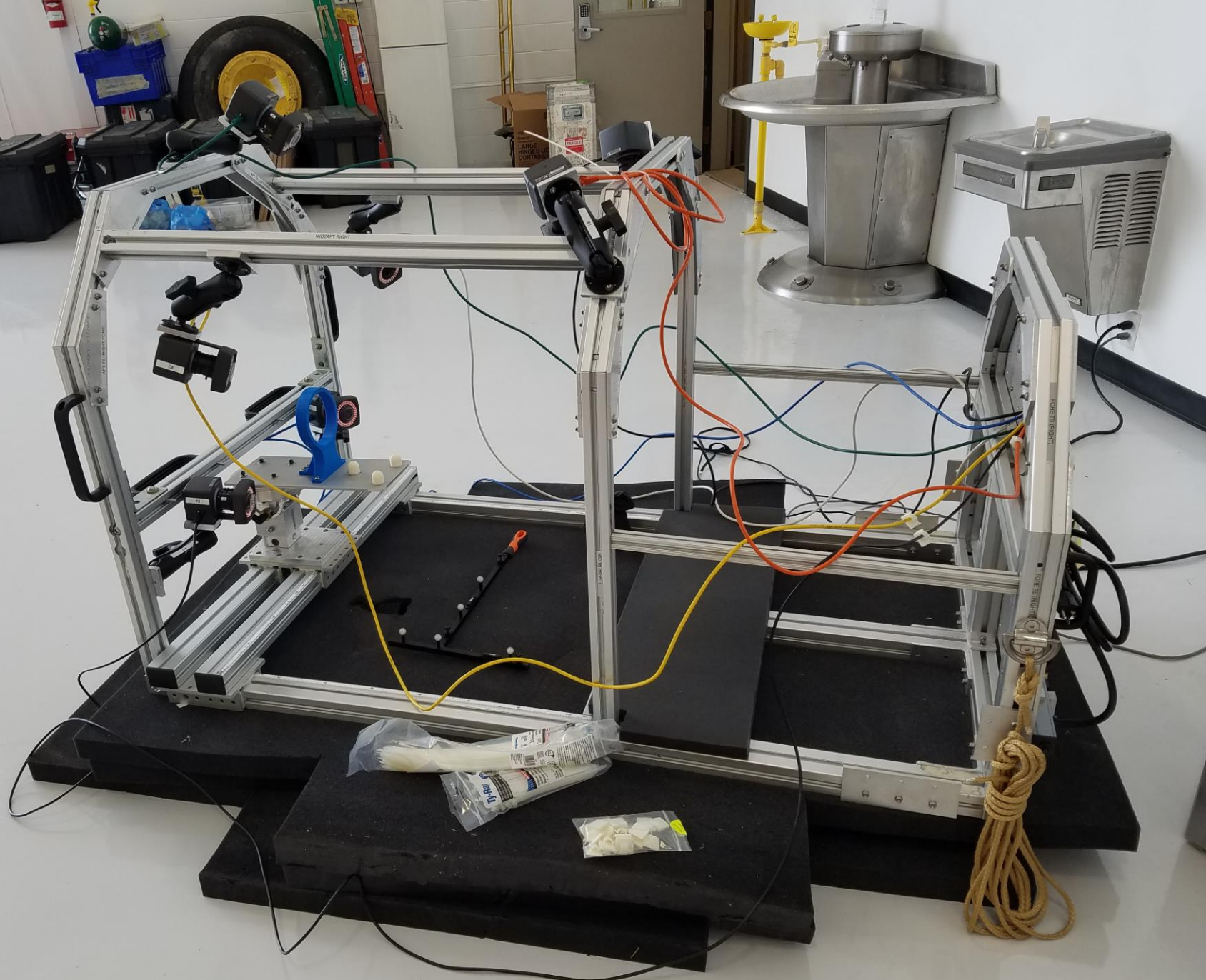
Arrival and Hangar Work



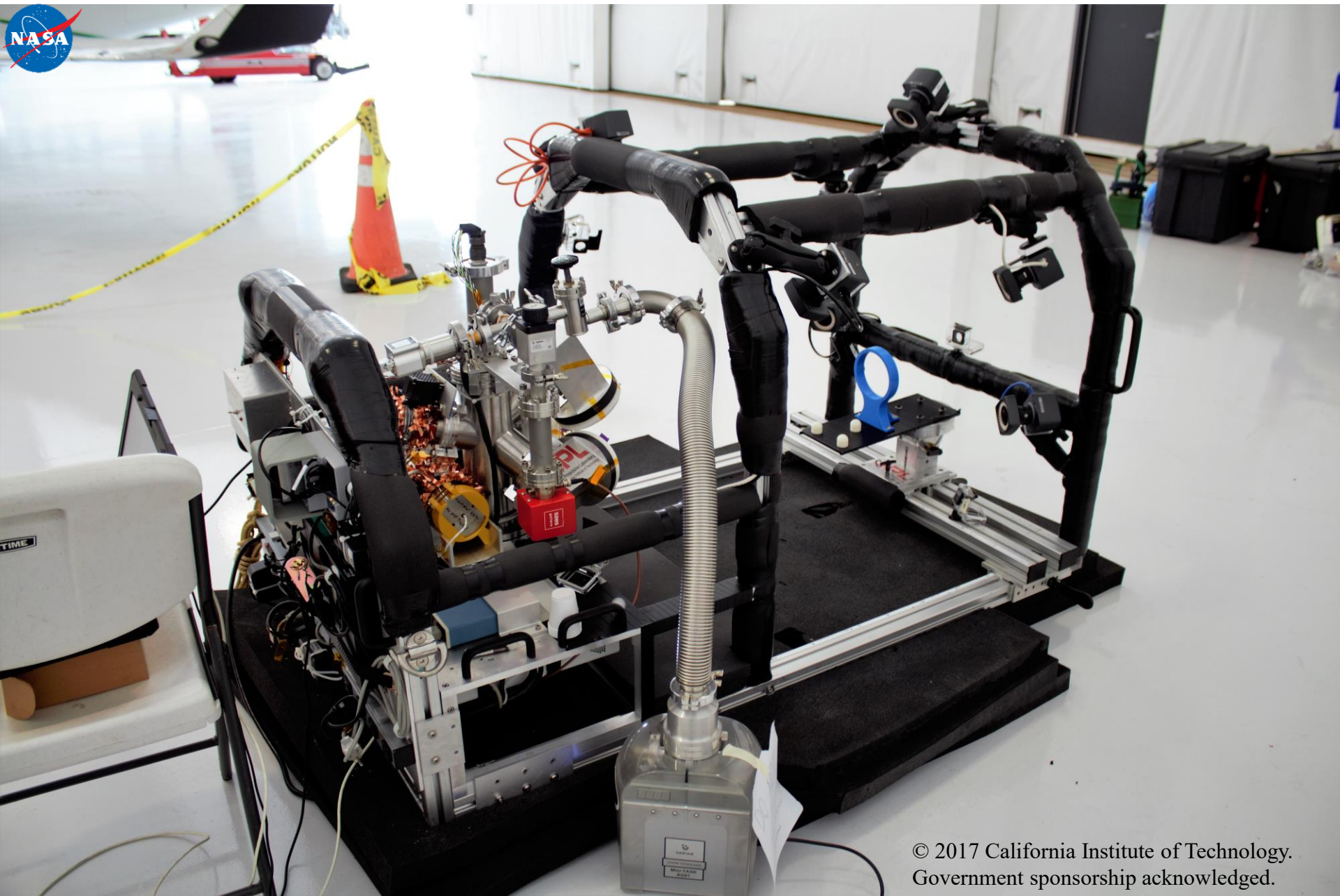


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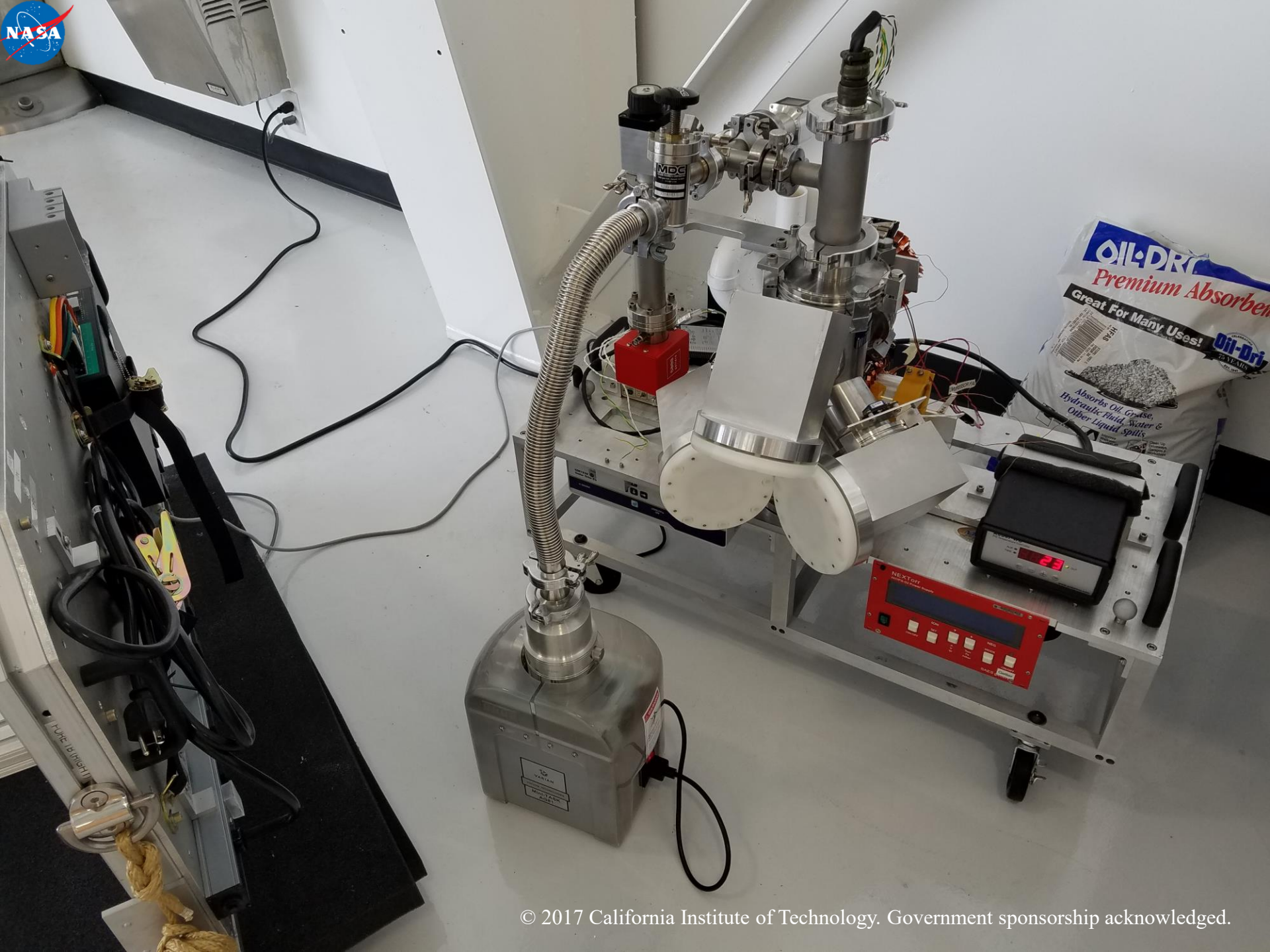




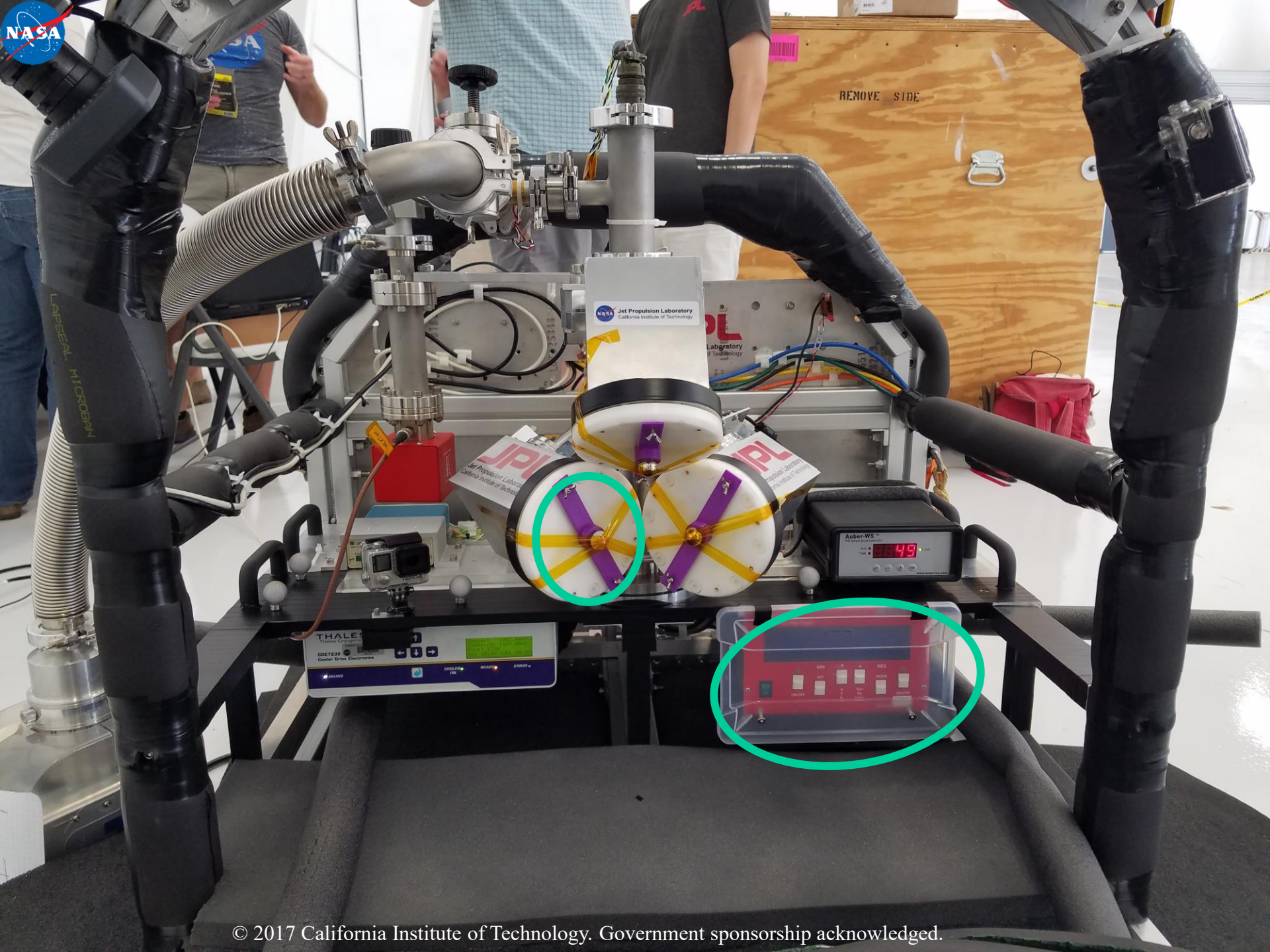


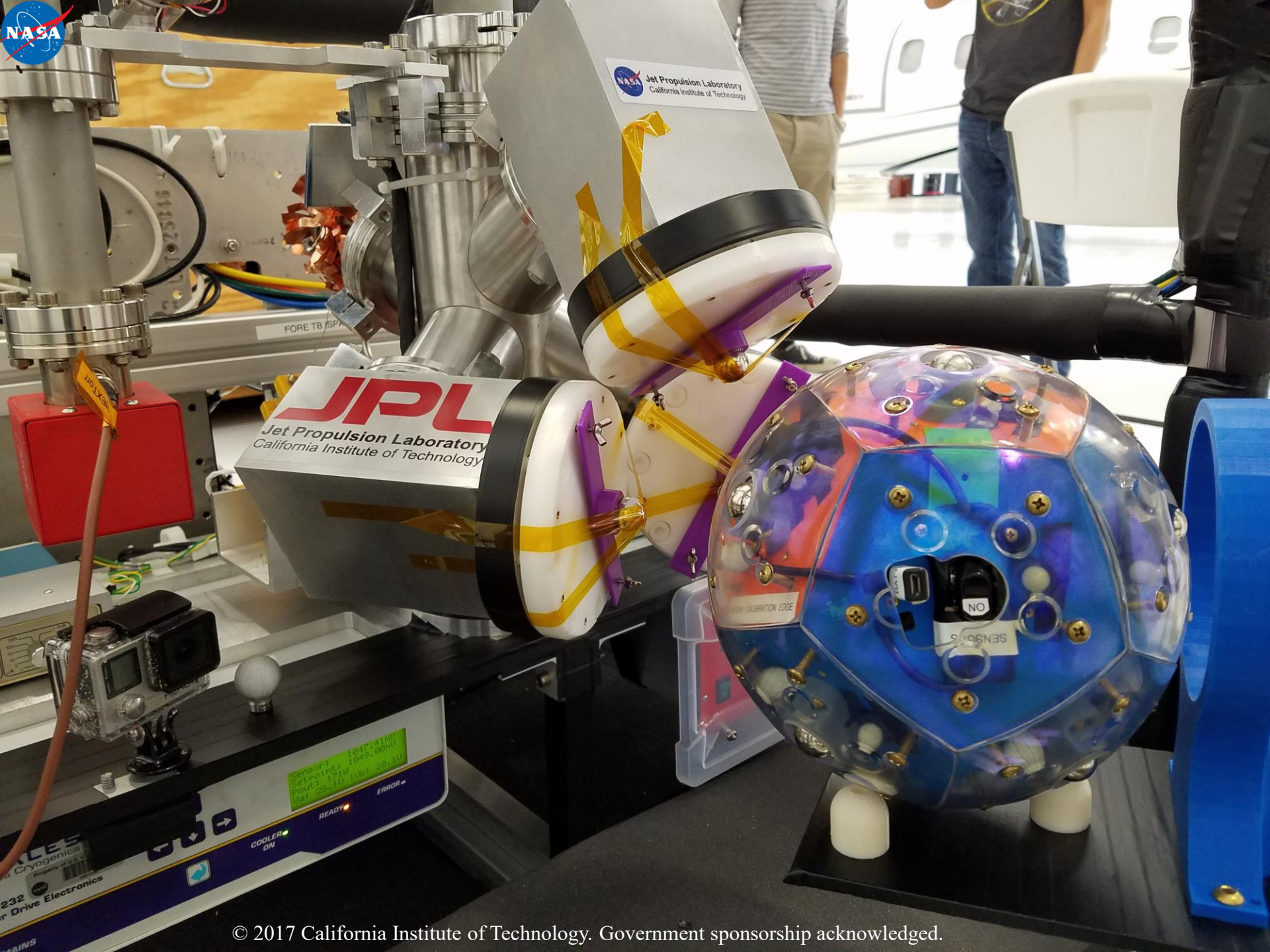
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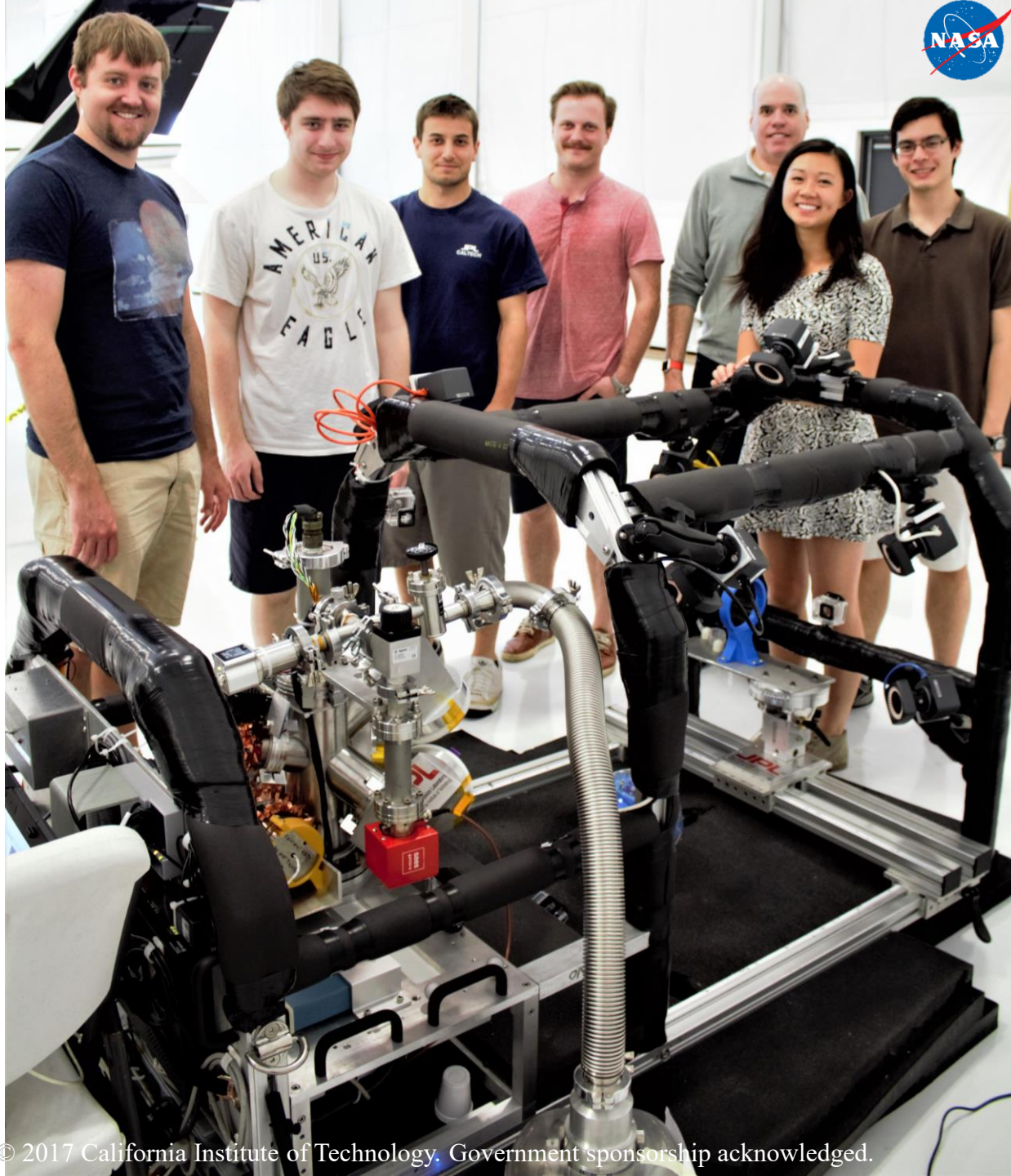
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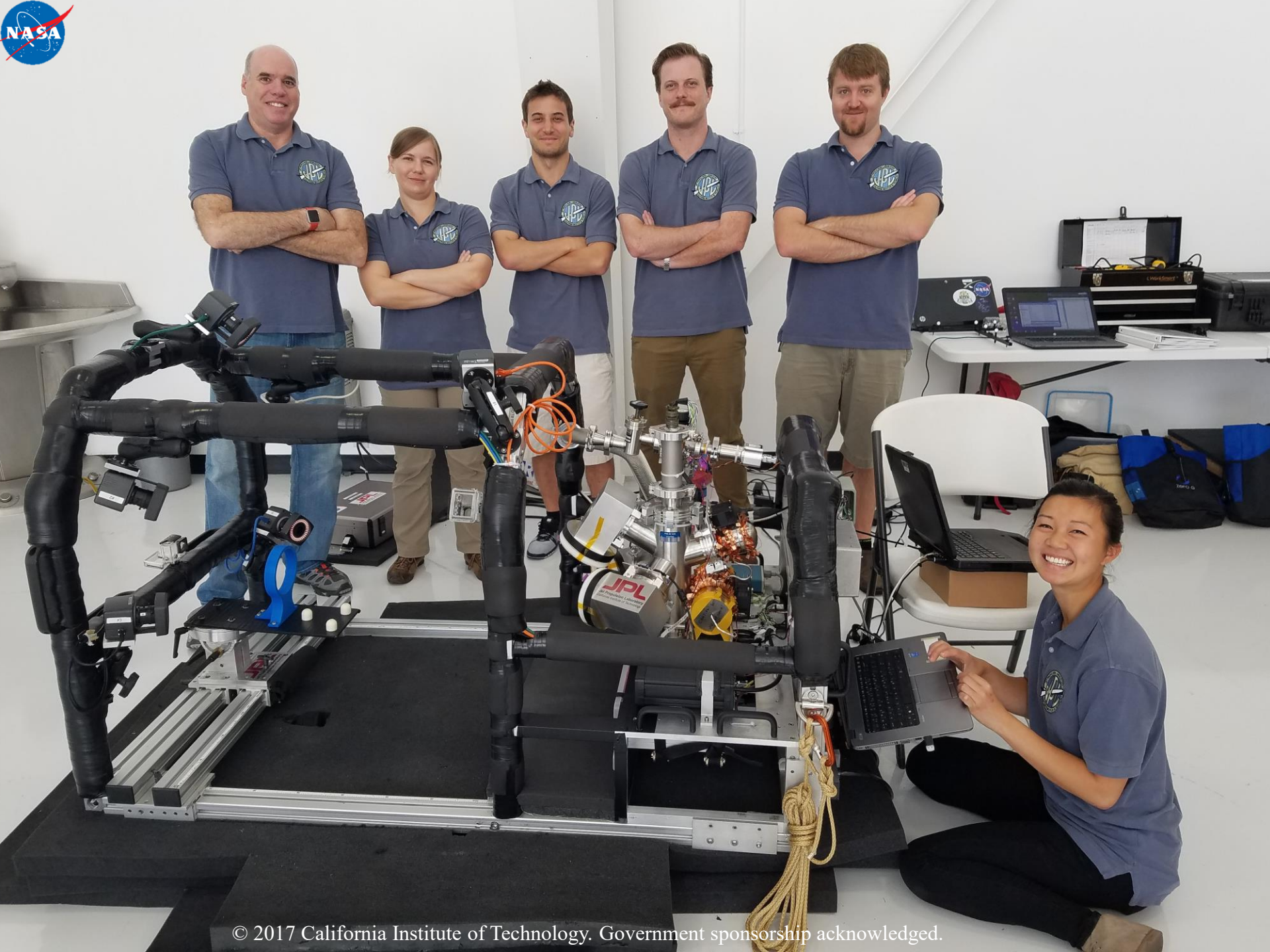






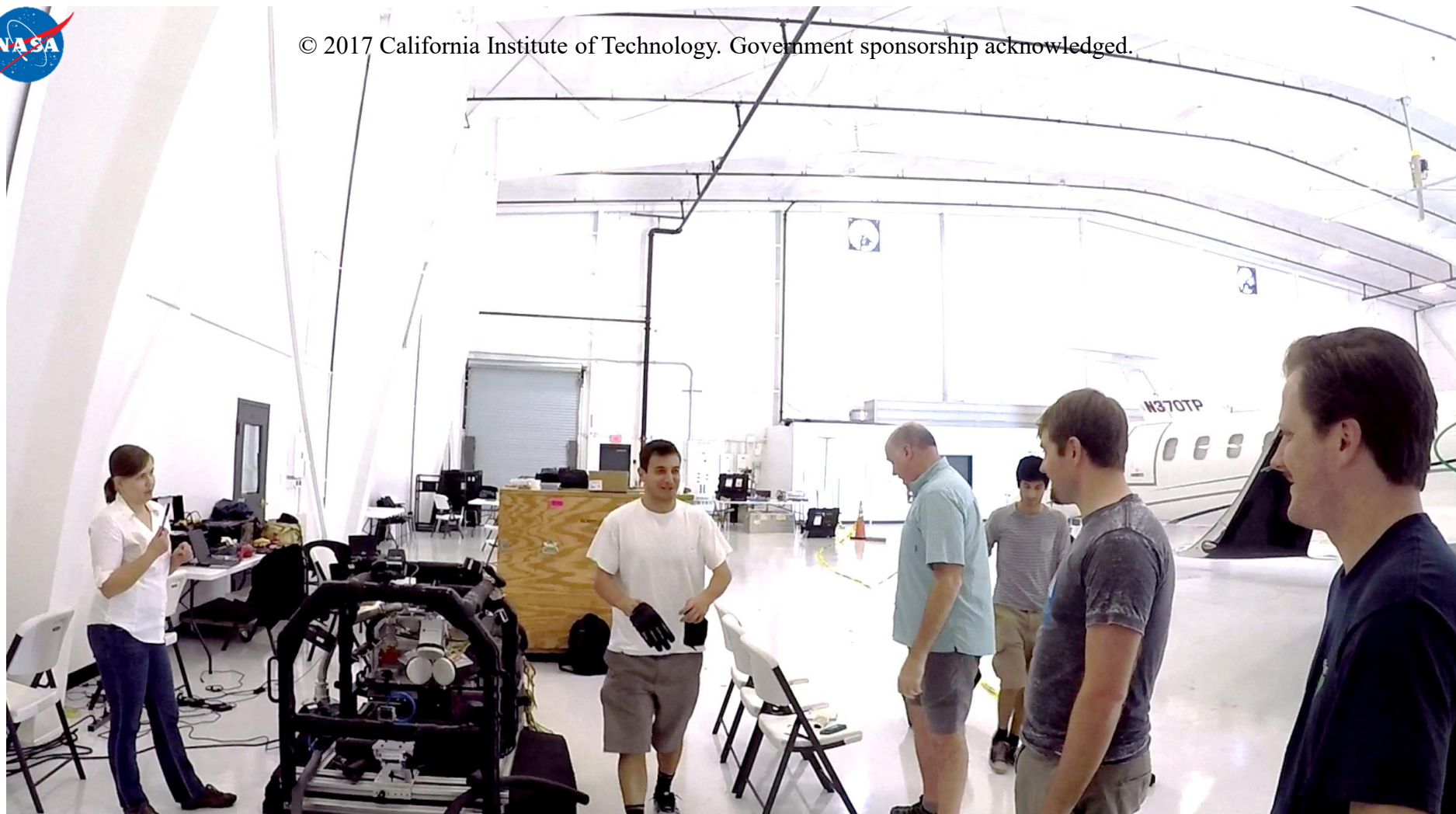








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TRR and Loading









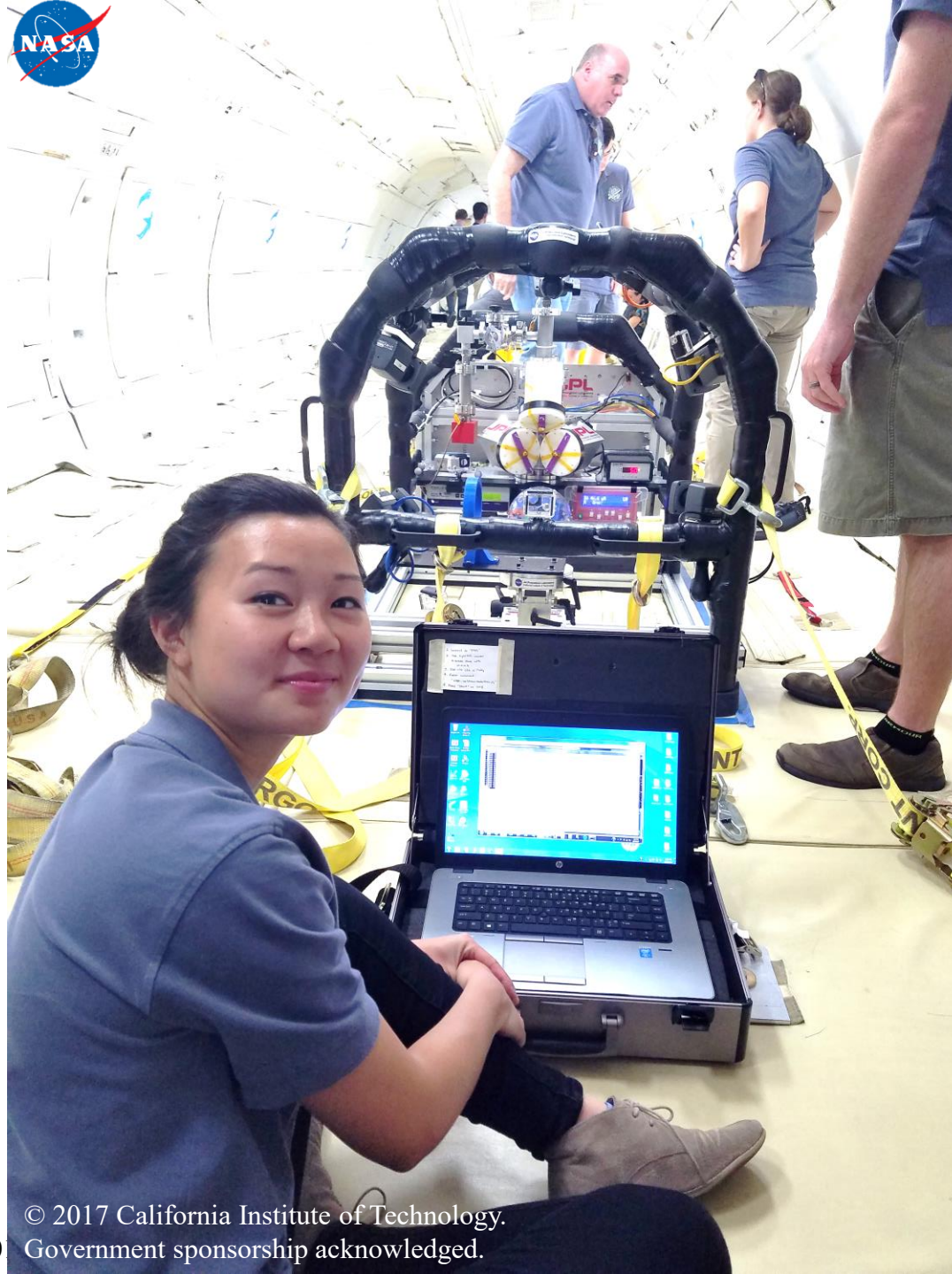
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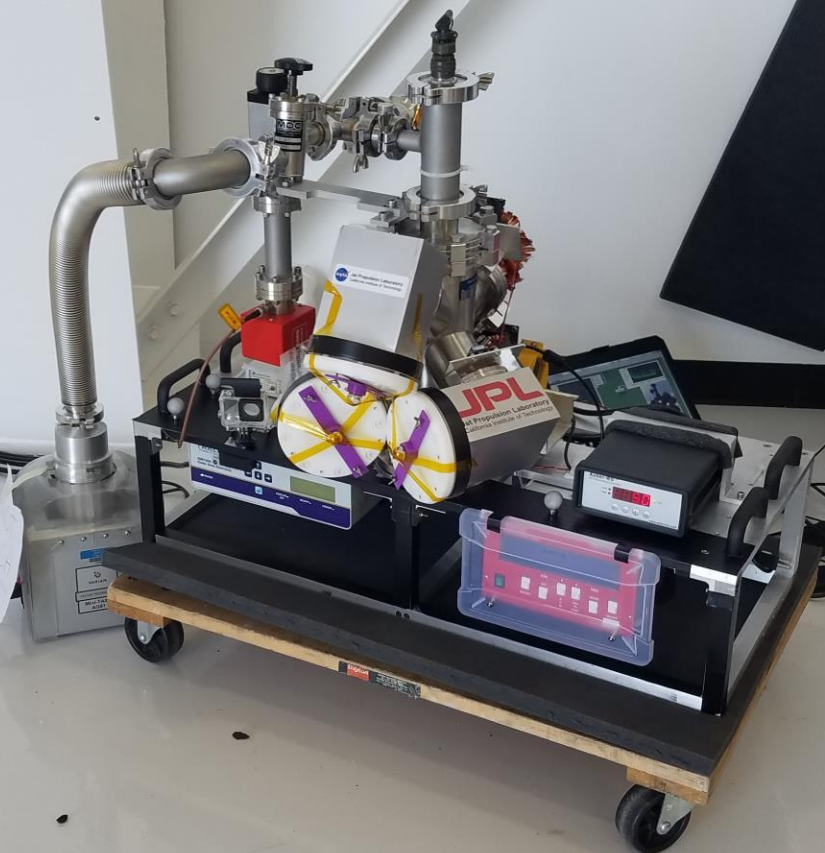


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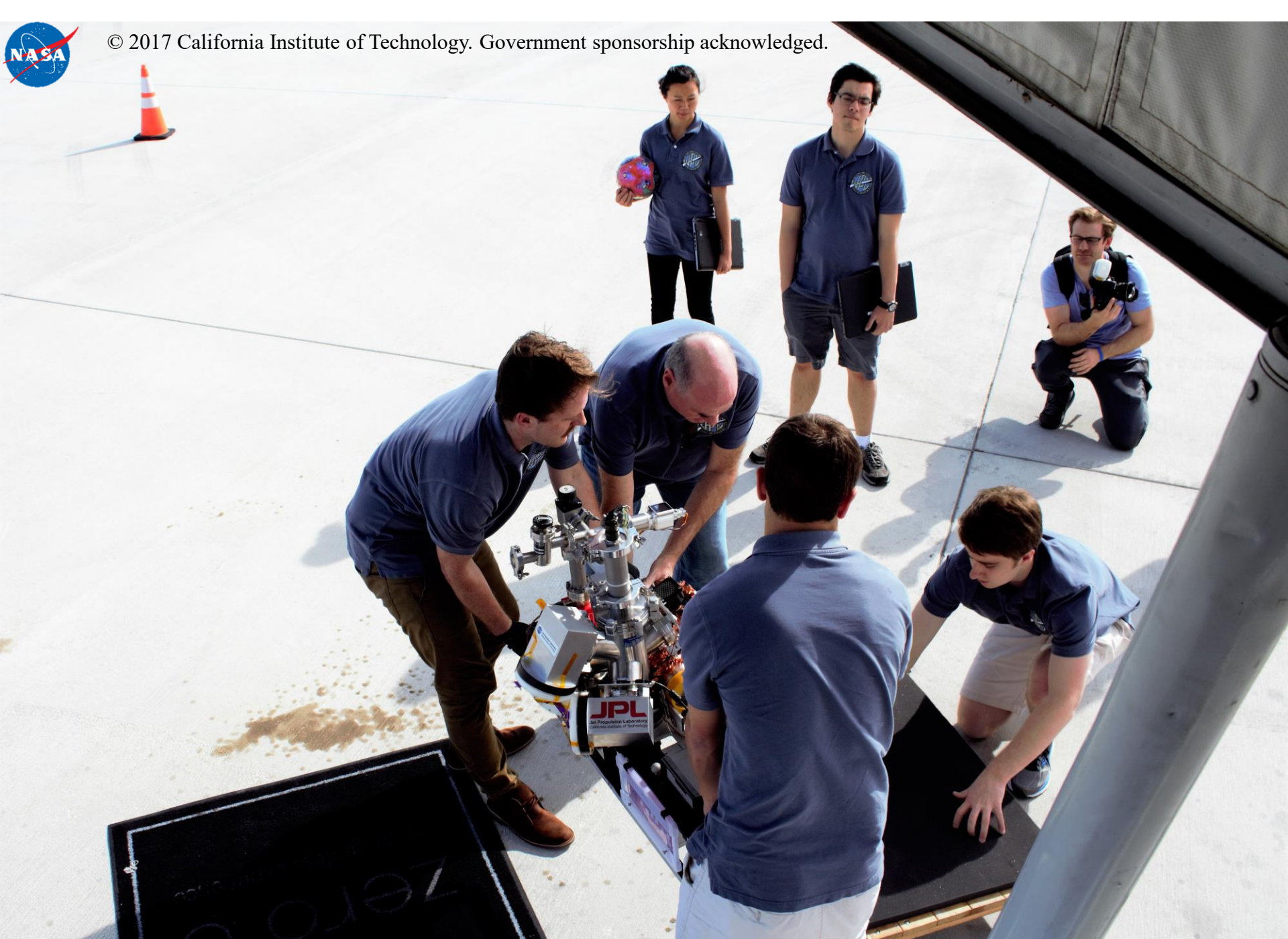


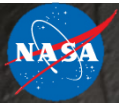




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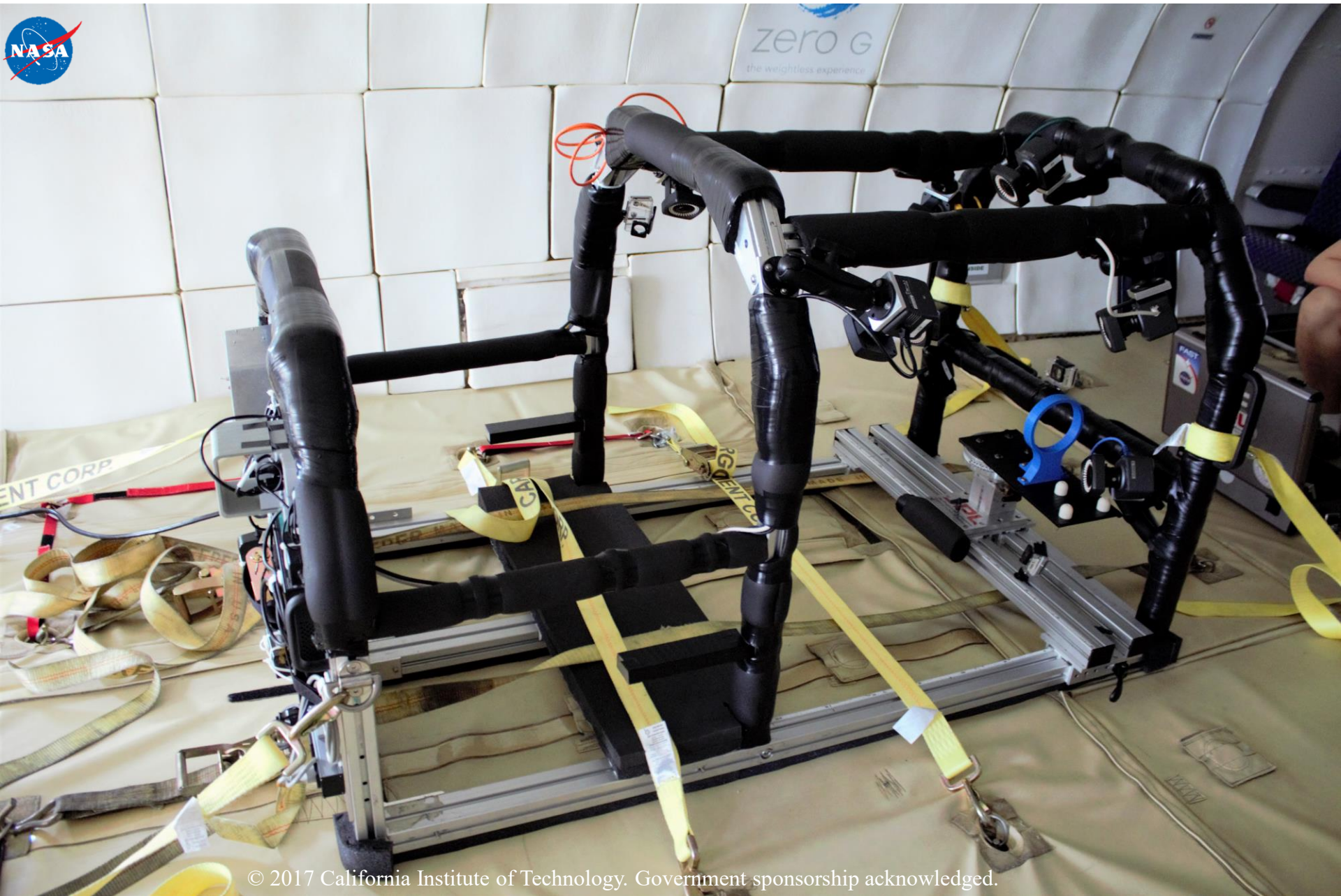


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Flight Experiments: Process





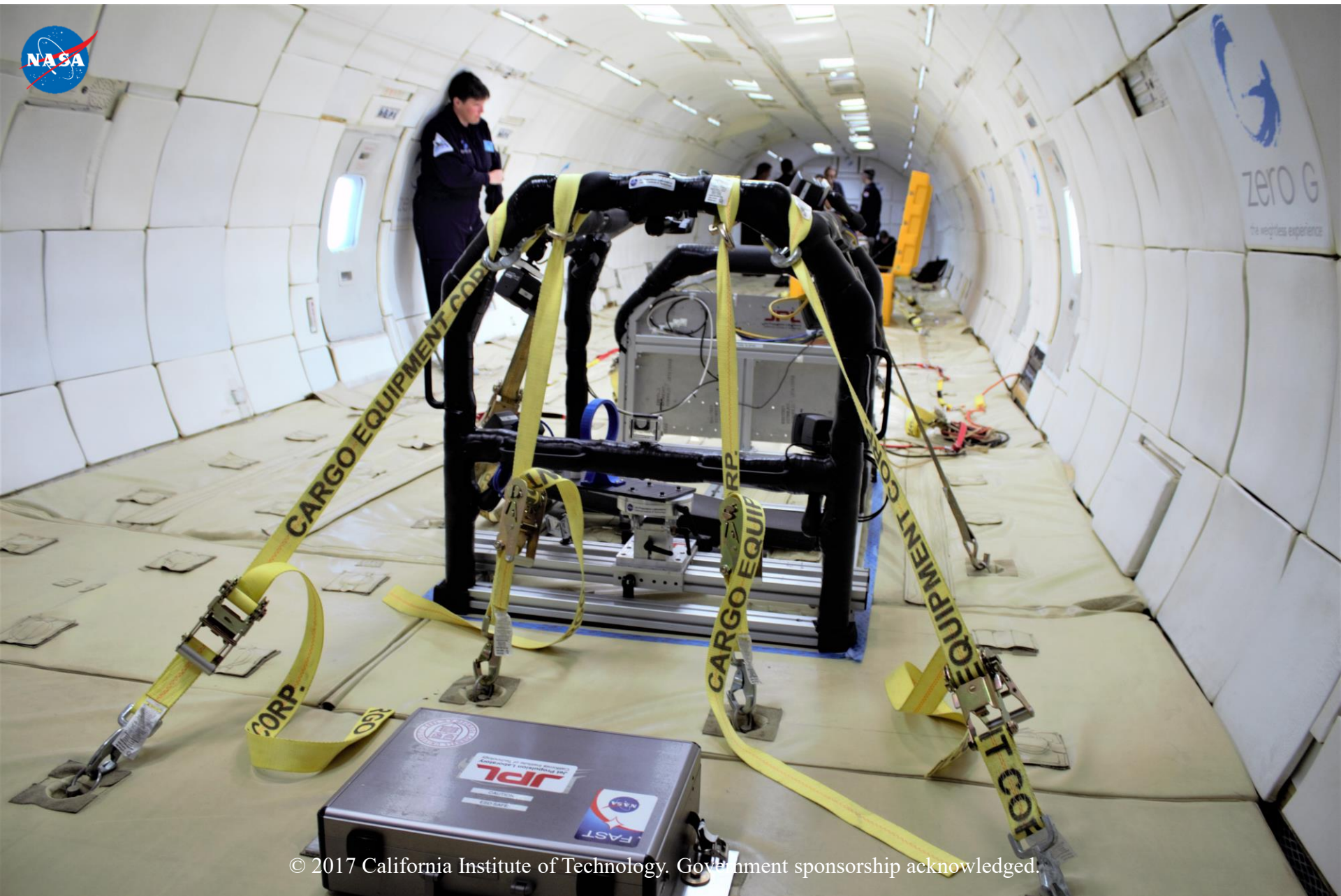
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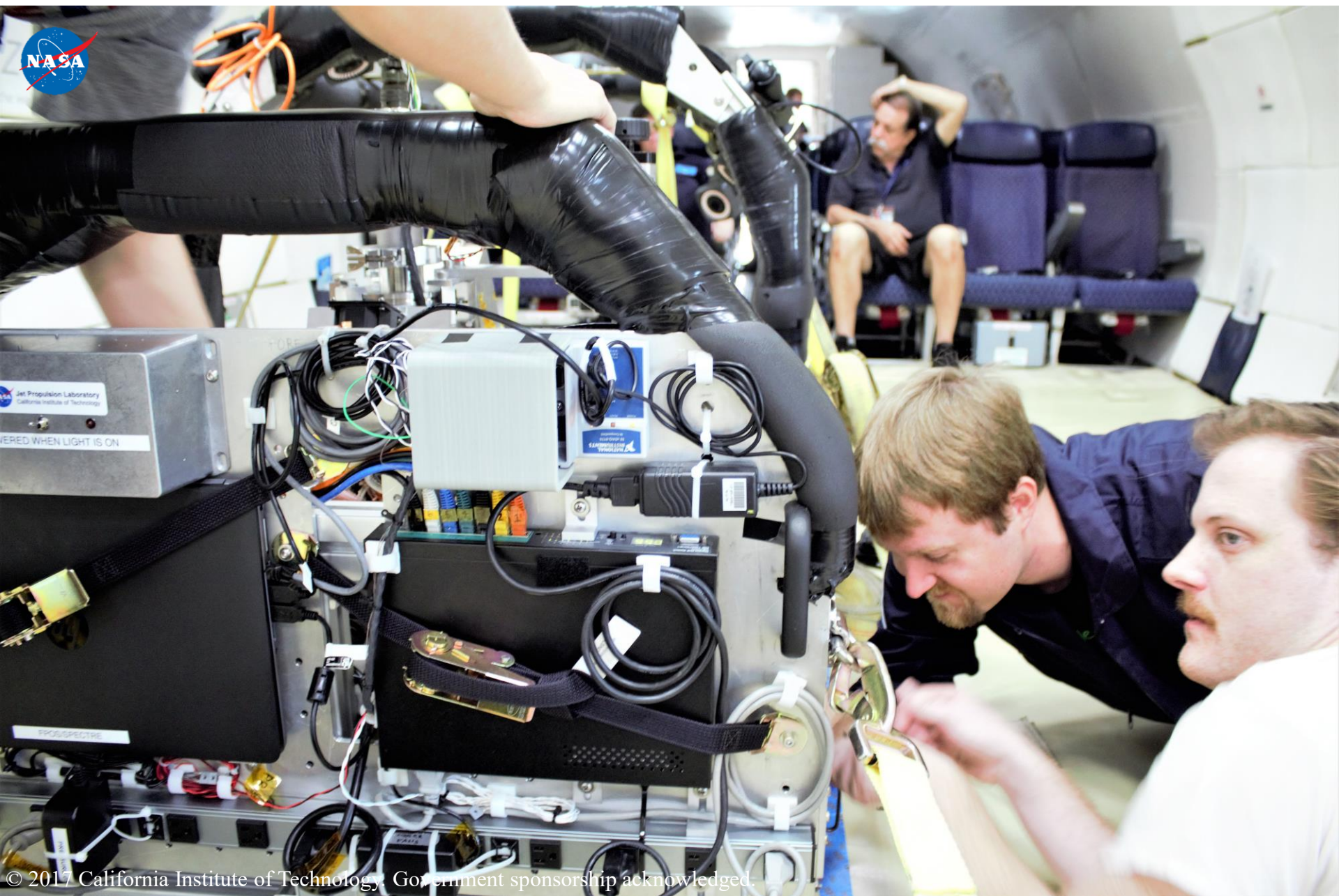
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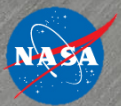




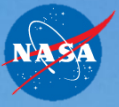








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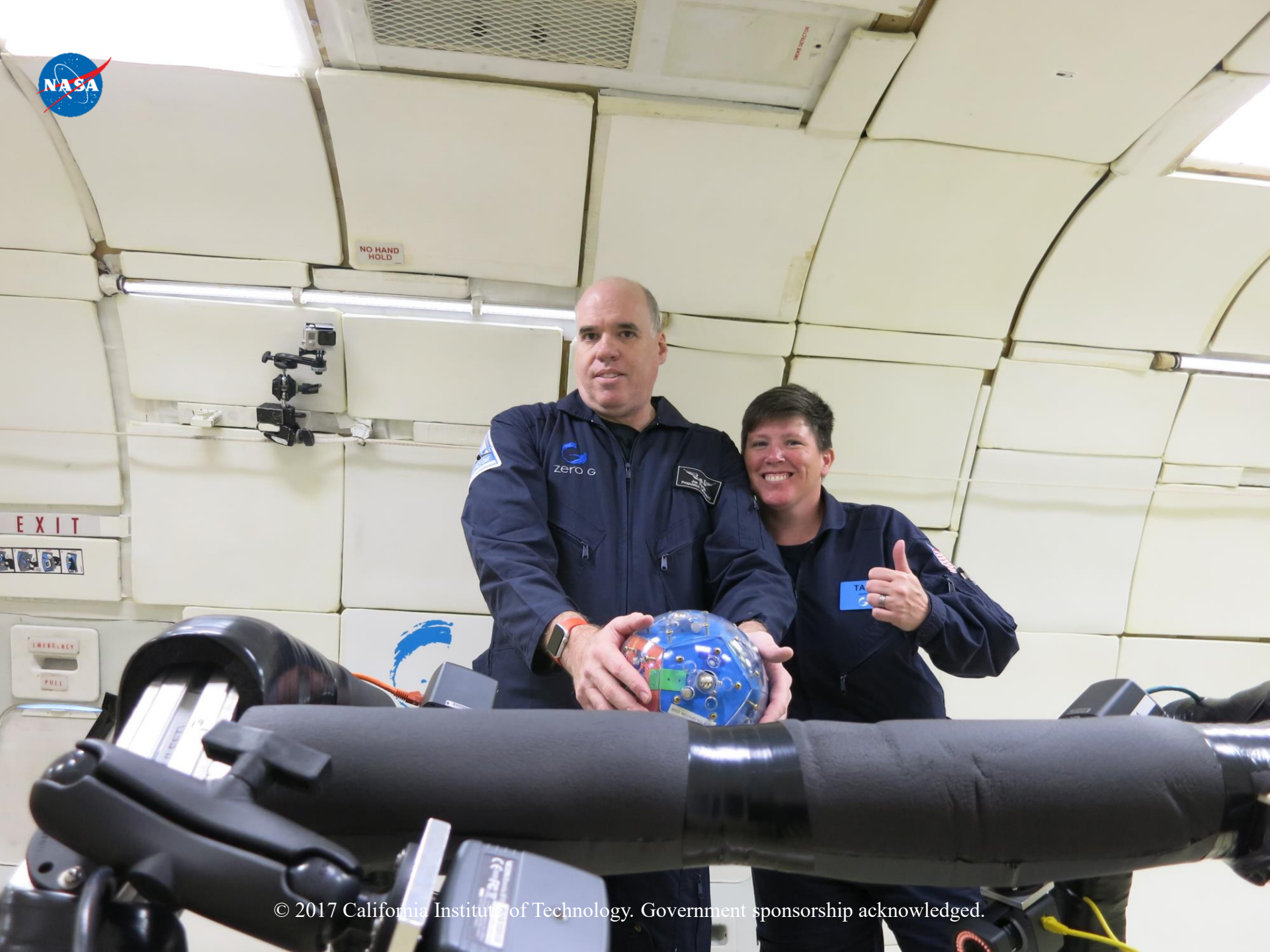


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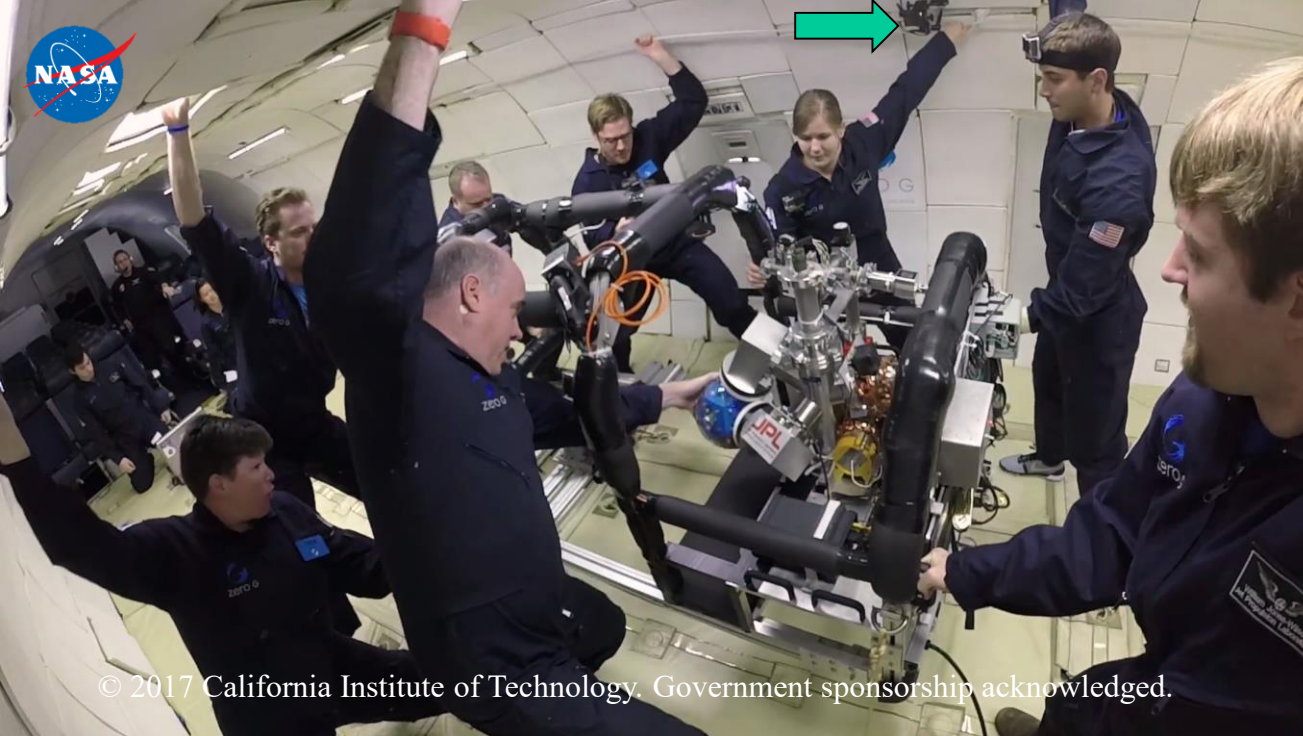




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Zero G
Camera 1

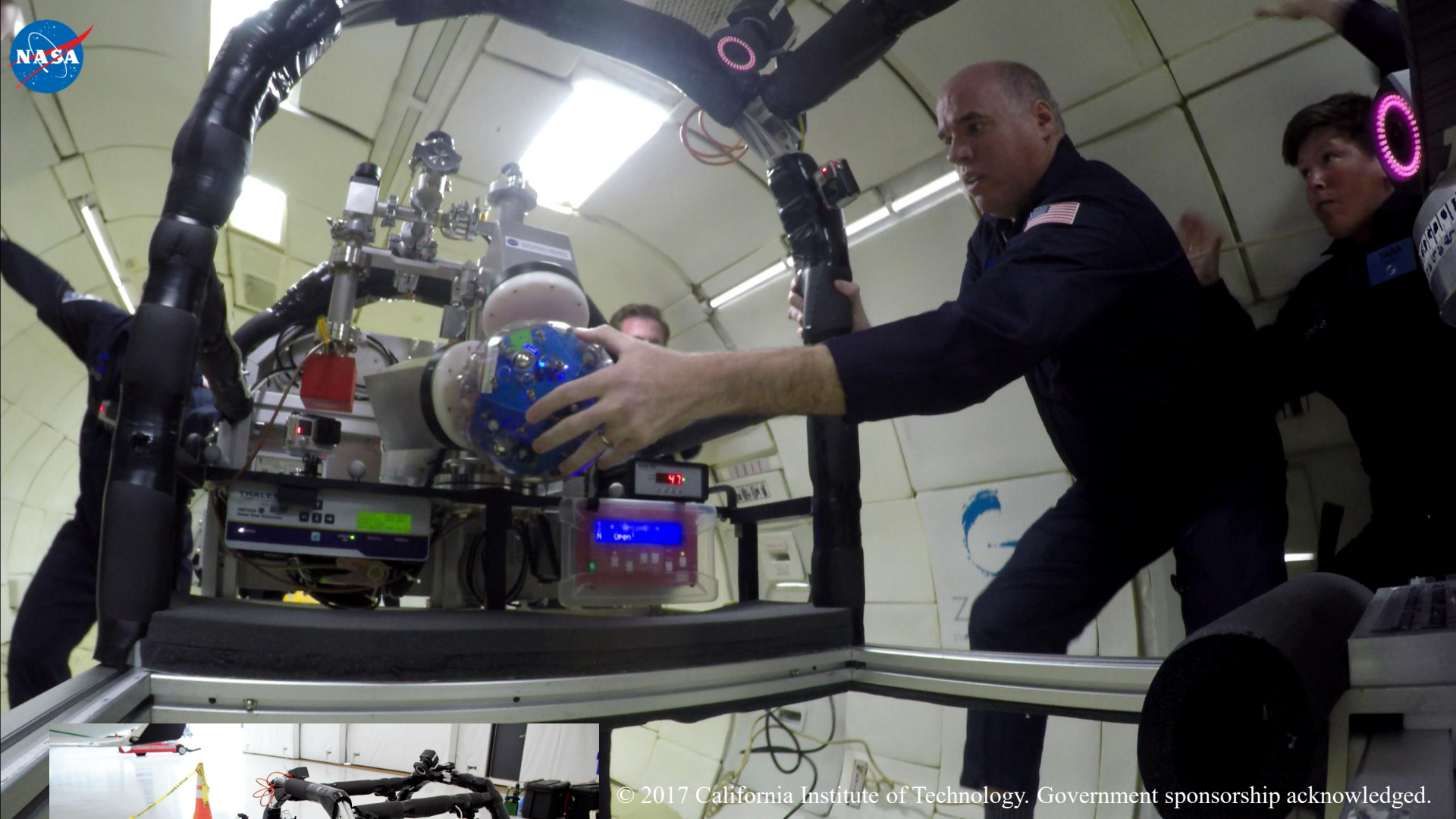
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Zero G
Camera 2

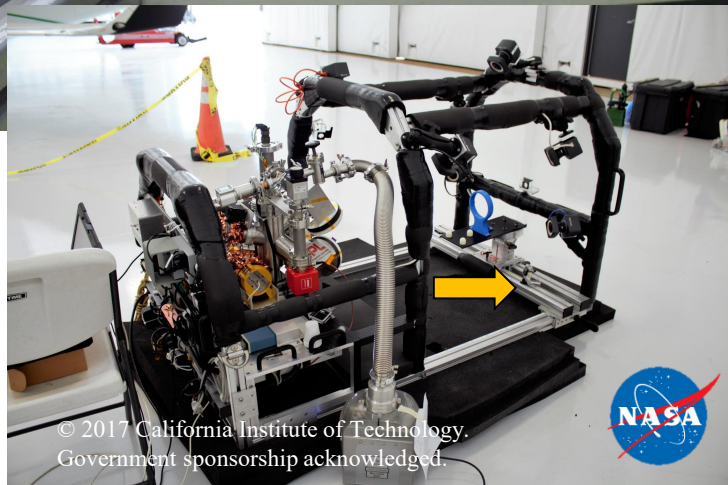
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Cam 1

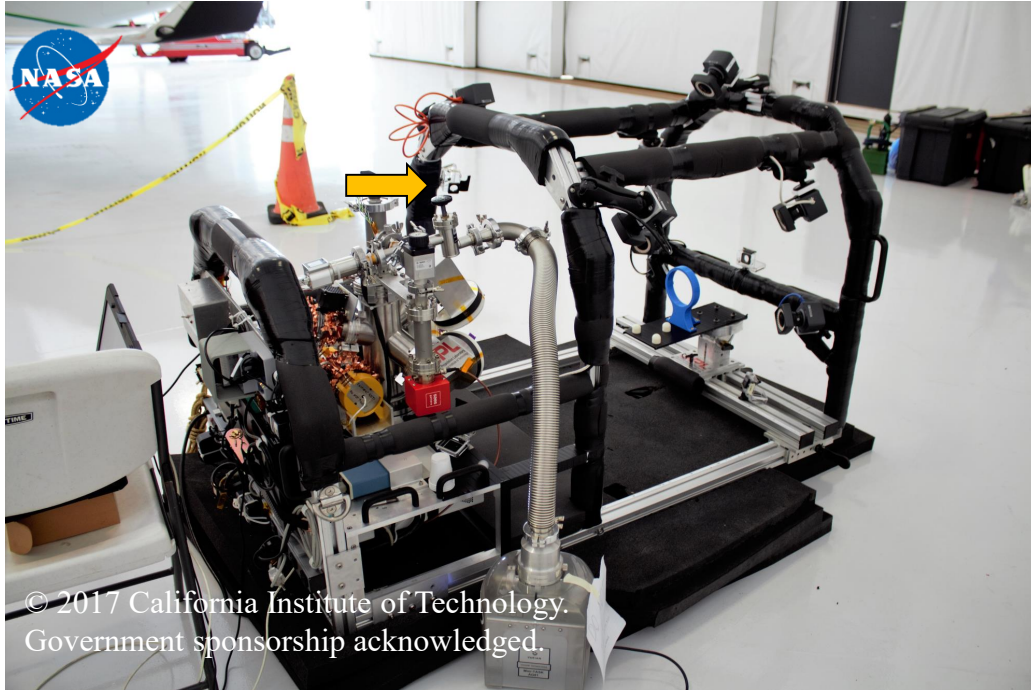


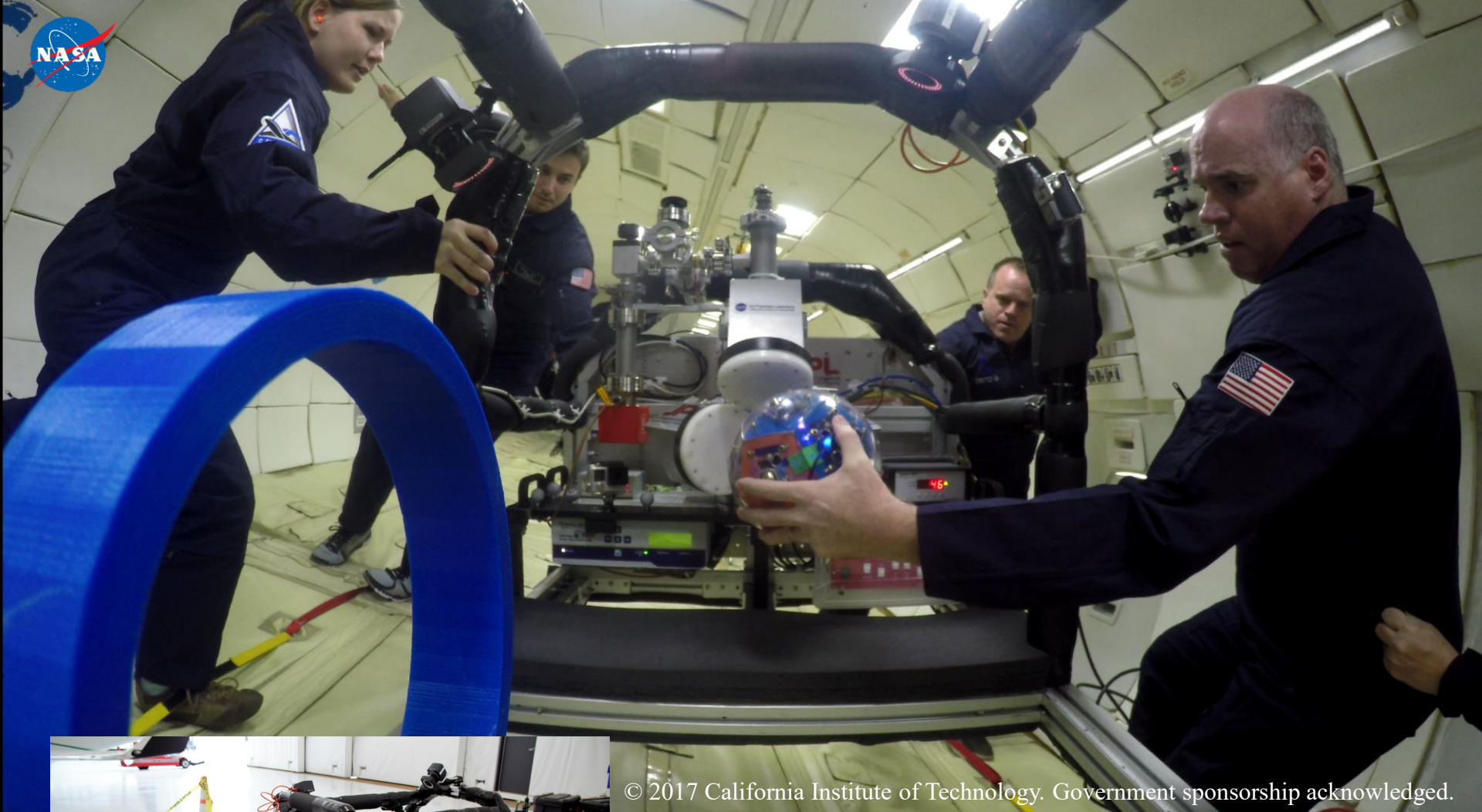
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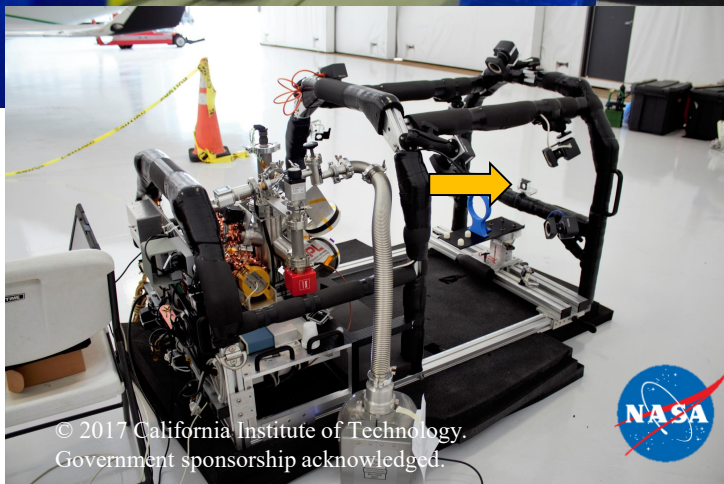
Cam 2





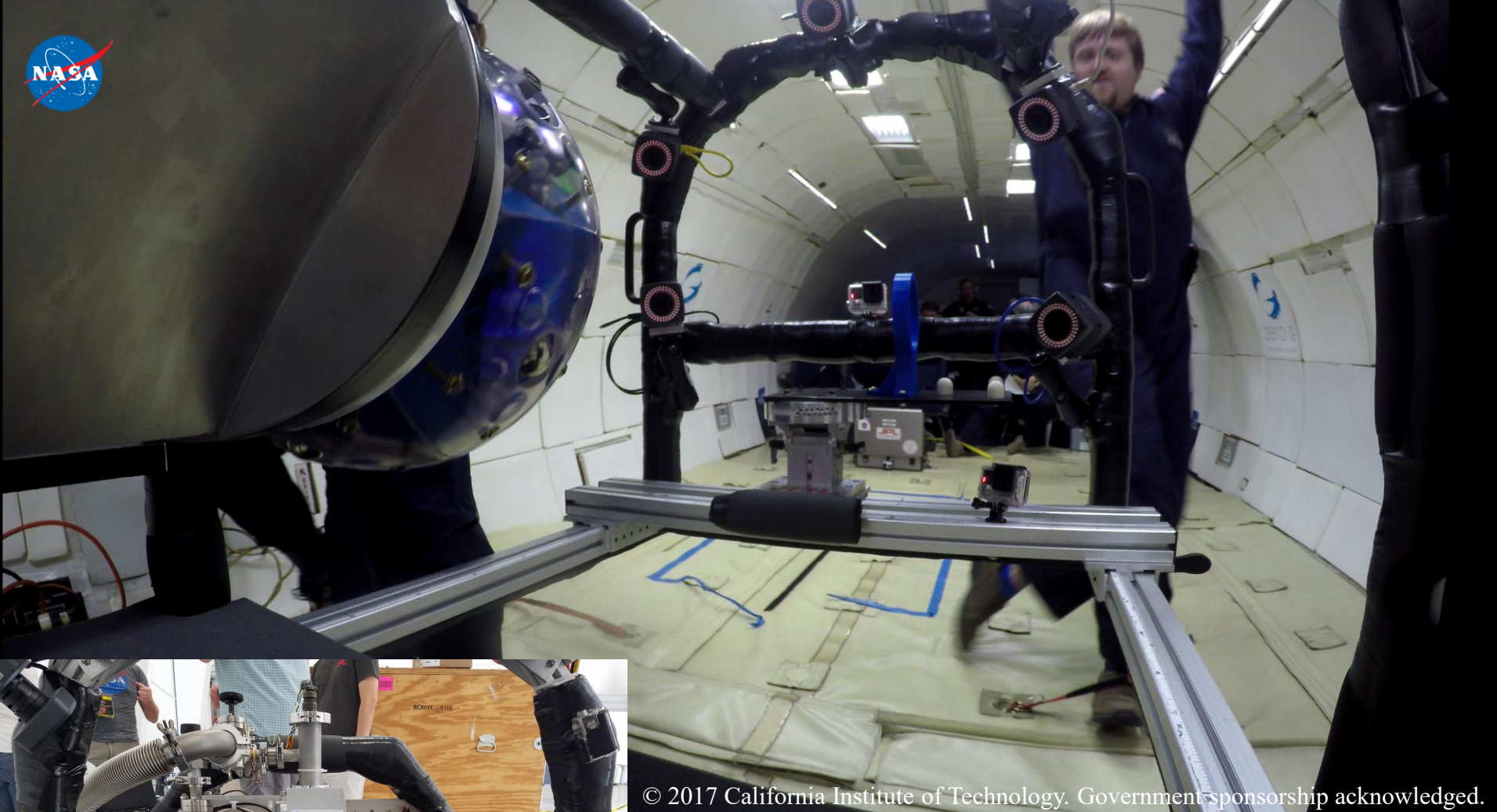
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Cam 3



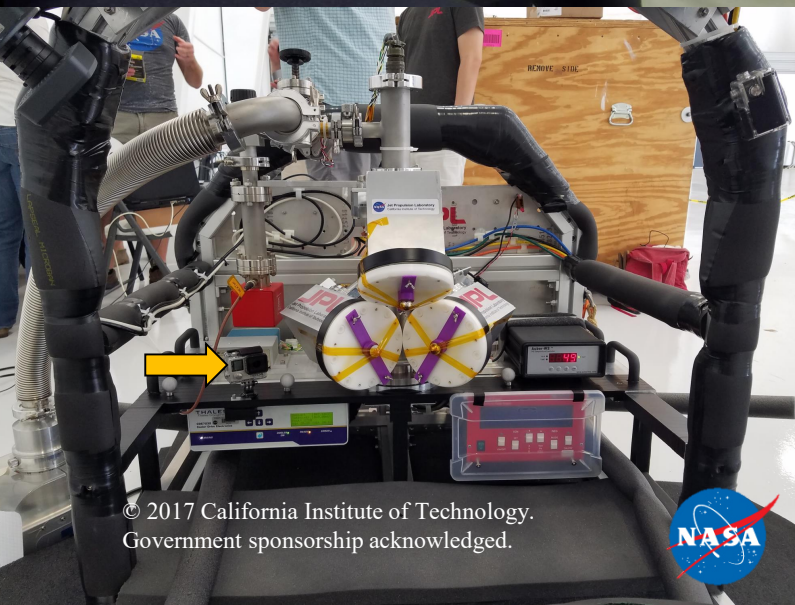
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Cam 4



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CLS Cam

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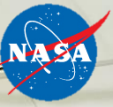


Josh Cam



Ian Cam





Eric Cam





Frankie Cam



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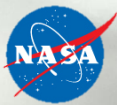


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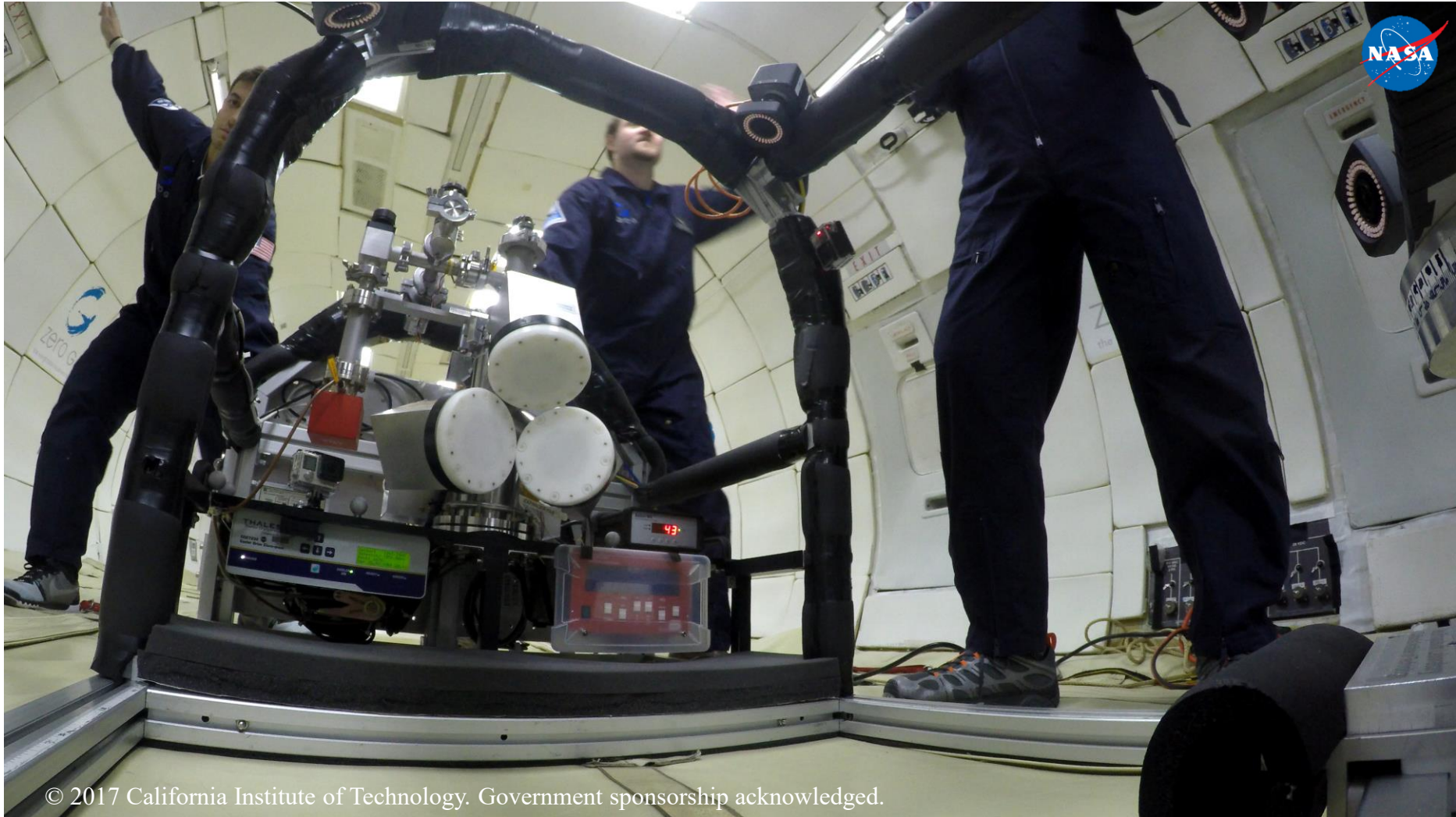


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Flight Experiments: Results



Equilibrium Float



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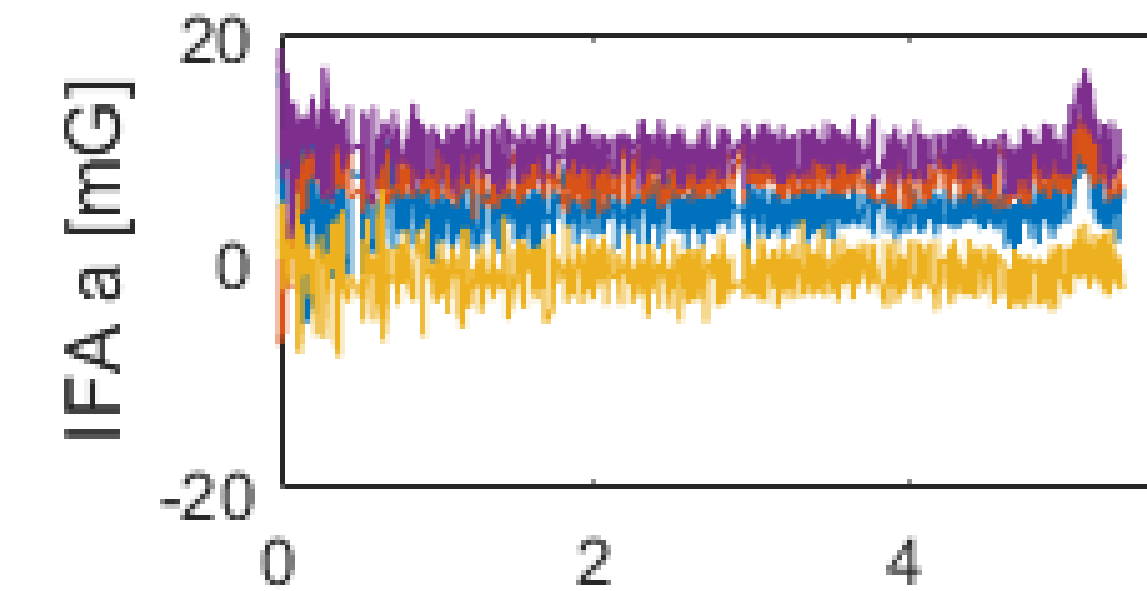
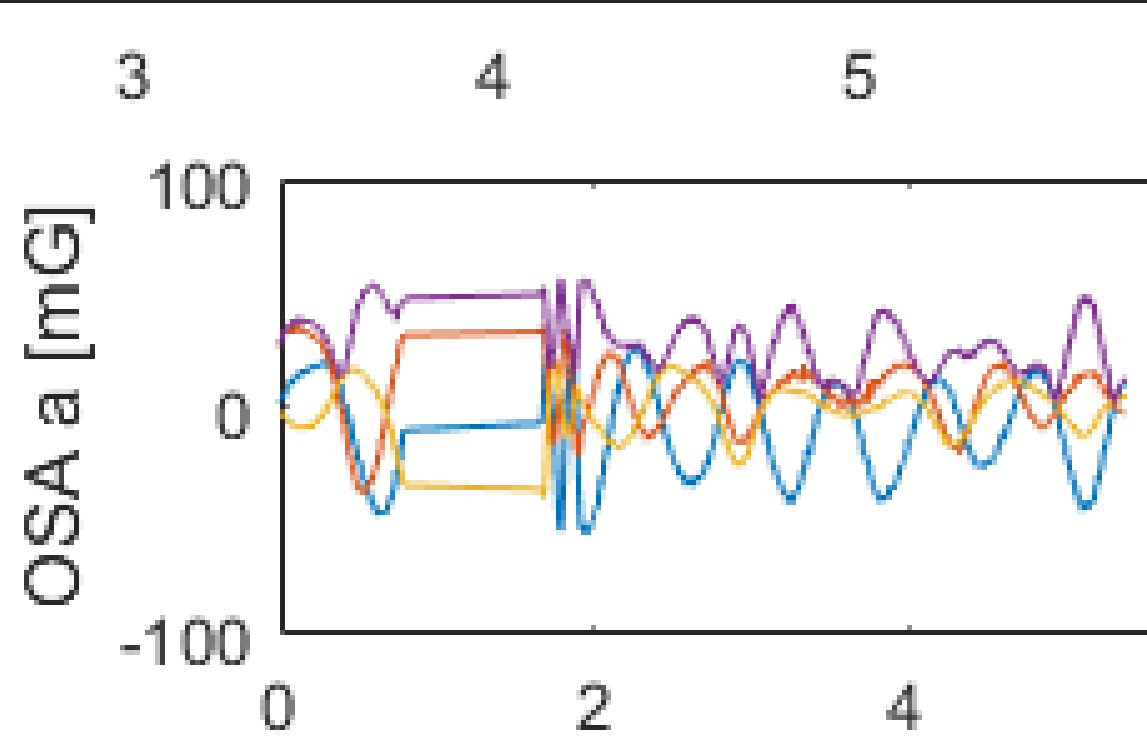
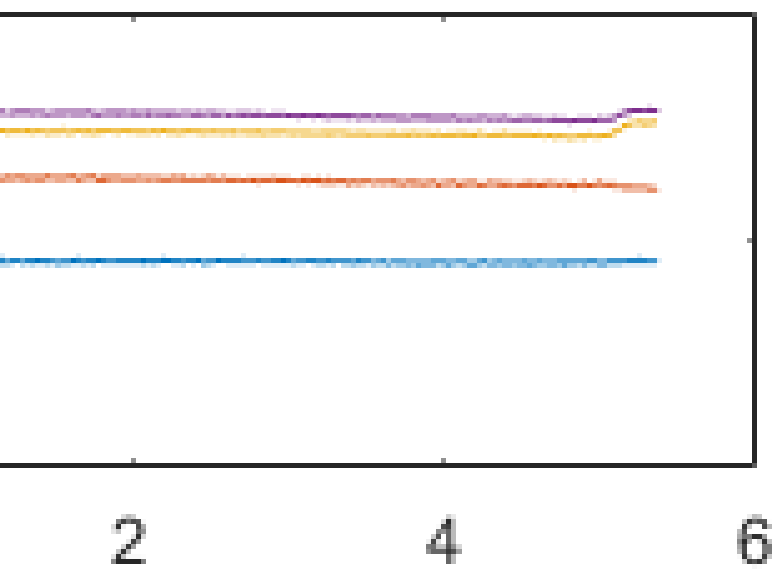
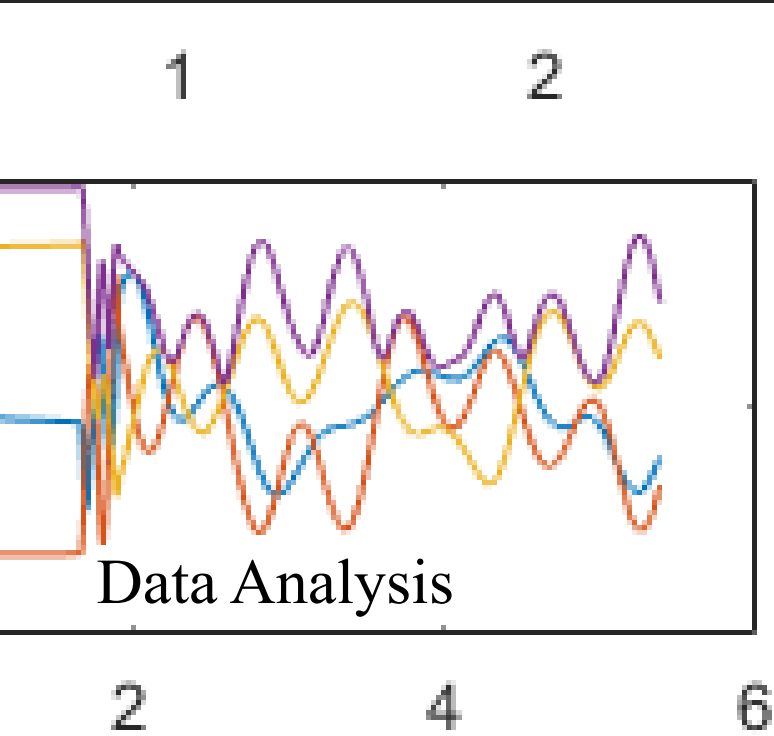
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Equilibrium Float



Equilibrium Float







Post-Flight Post-Processed Resources



- 32 hours of footage = 2 days * 2 hours of footage/day * 8 camera views. Around 350 video clips each day! Video clips and high level notes found at this [Cornell Box folder](#)
- Experiment notes can be found at this [Google Drive link](#). Currently only coarse notes for video snips
- OSA IMU, frame IMU, Vicon camera system, and SROA sensor data found in this [Cornell Box folder](#). Raw data snippets can be found in subfolders



Flight Day Statistics



- Day 1: Out of 50 attempted experiment runs, 19 trials yielded clean data.

Vicon data?	OSA data?	IFA data?	Contact?	Capture?
9	19	19	11	13
No contact, Capture	Contact, Capture	No contact, Escape	Contact, Escape	
6	7	1	4	

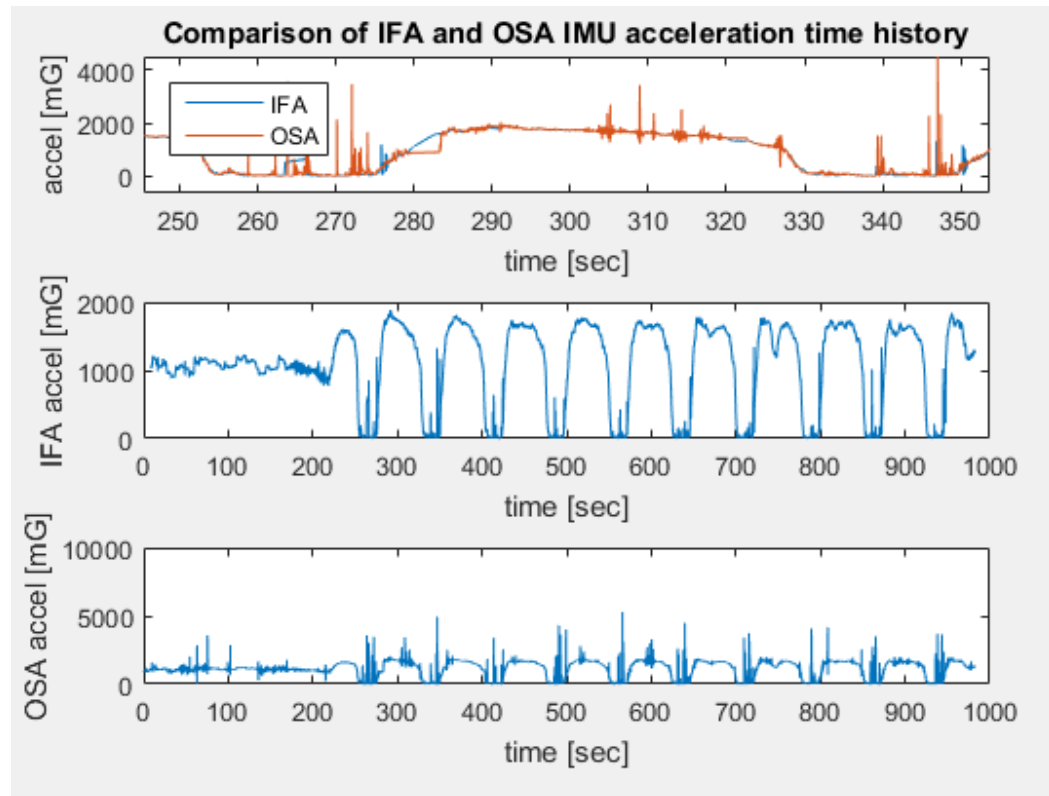
- Day 2: Out of 47 attempted experiment runs, 32 trials yielded clean data.

Vicon data?	OSA data?	IFA data?	Contact?	Capture?
30	32	32	17	18
No contact, Capture	Contact, Capture	No contact, Escape	Contact, Escape	
13	5	2	12	

Time Synchronization Sample



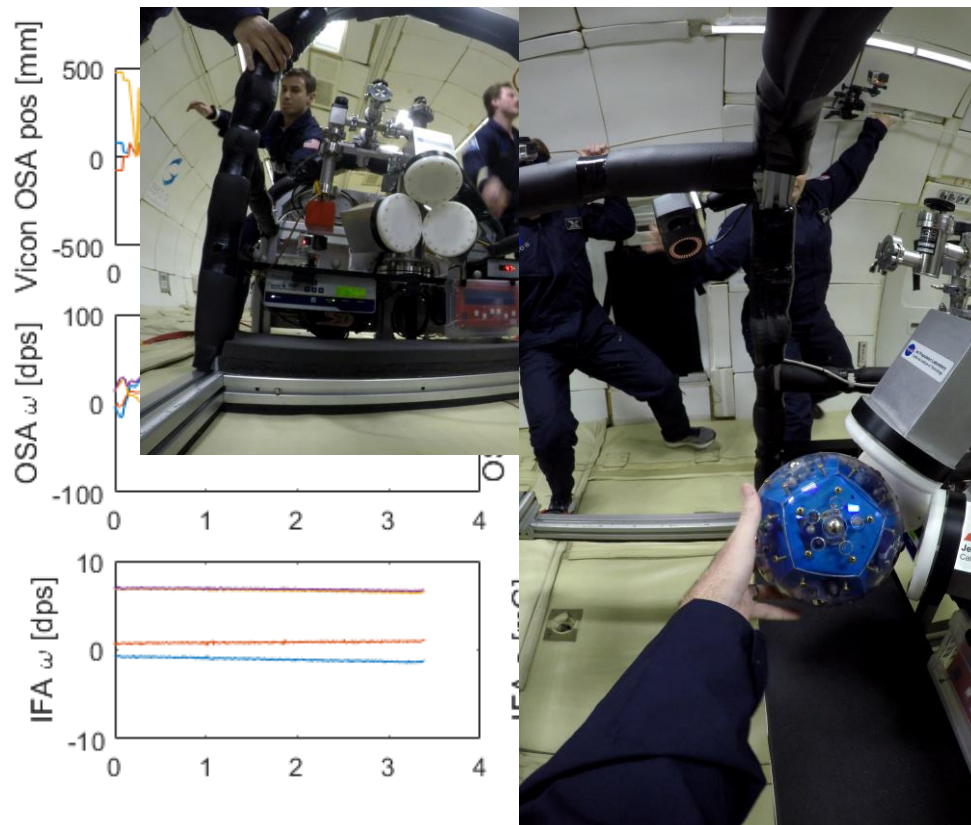
- Vicon and frame IMU use sensing computer's clock
- OSA IMU is initialized by sensing computer's clock at beginning of experiment
- OSA and IMU acceleration profiles match very well... but foreshadowing, still latency issue on the magnitude of milliseconds



Sample Tests and Interpretation



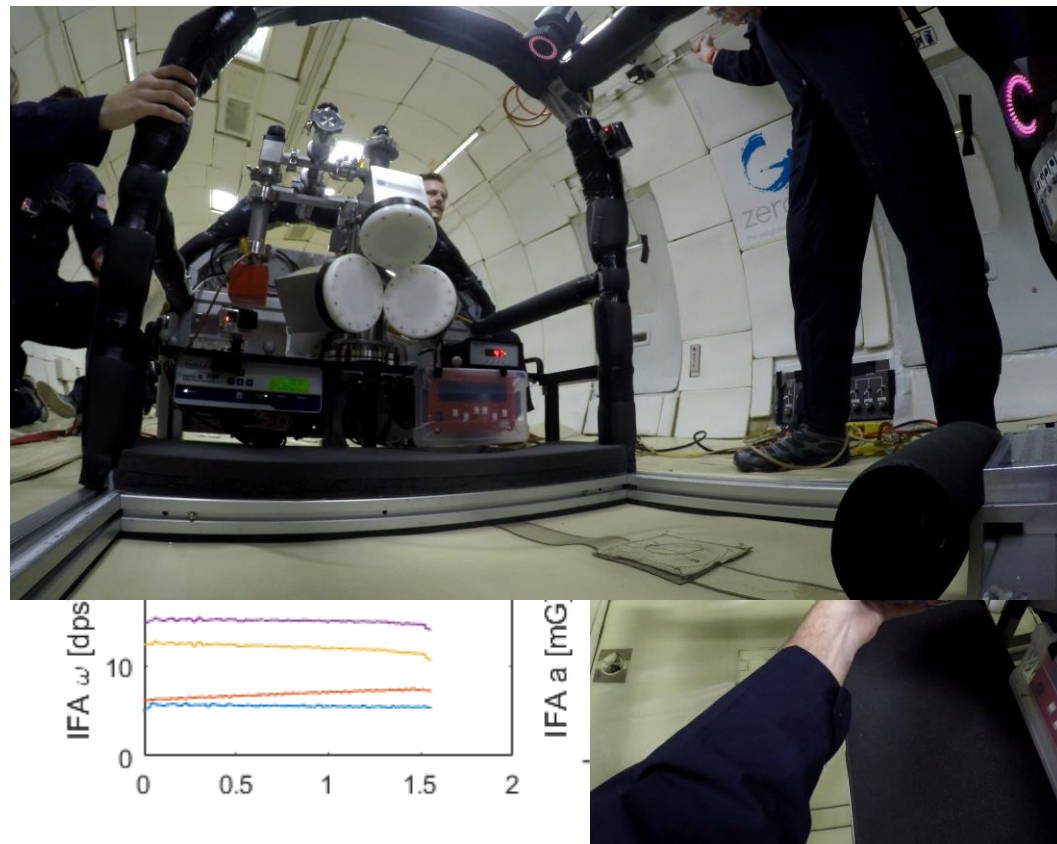
- First clean trial! OSA oscillating in equilibrium
- Jolty Vicon data. Object tracking software confused and resolving false position and orientation.
- OSA IMU dropout between 2 and 3 seconds
- Many OSA contacts with SROA. SROA IMU also reflects initial impact at 1 sec.
- IFA angular velocity steady, inertial environment



Sample Tests and Interpretation



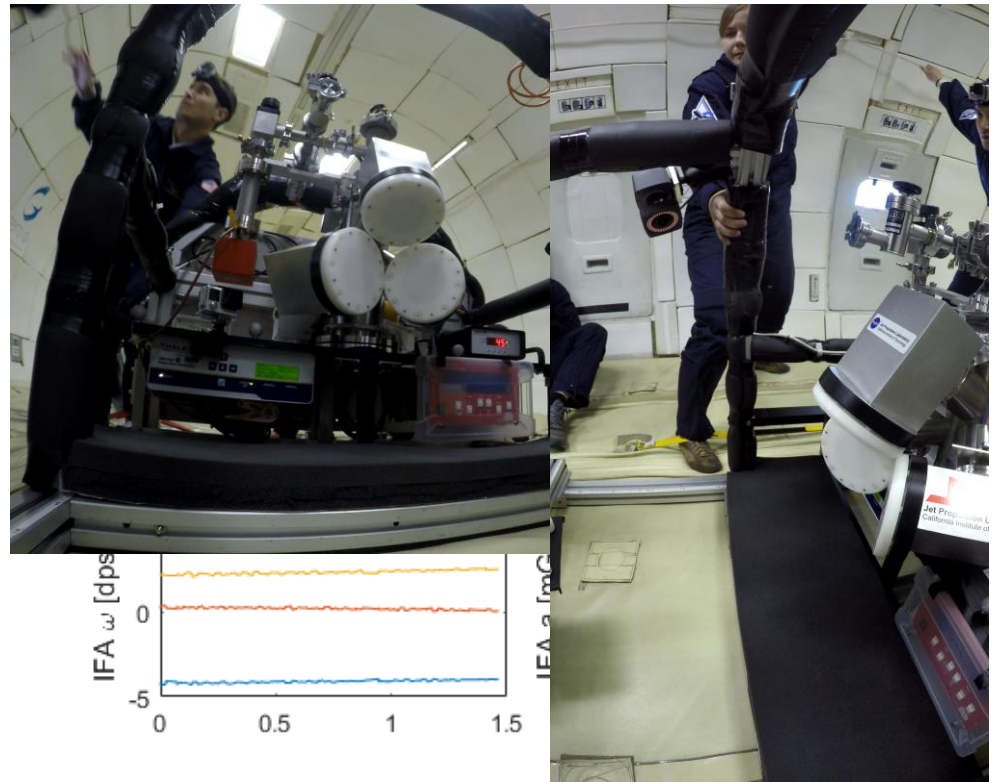
- No contact and escape
- Beautiful Vicon data
- OSA comes in with angular velocity; FP reorients OSA upon ejecting it from potential well (too much KE); OSA decelerates
- IFA angular velocity steady, inertial environment



Sample Tests and Interpretation



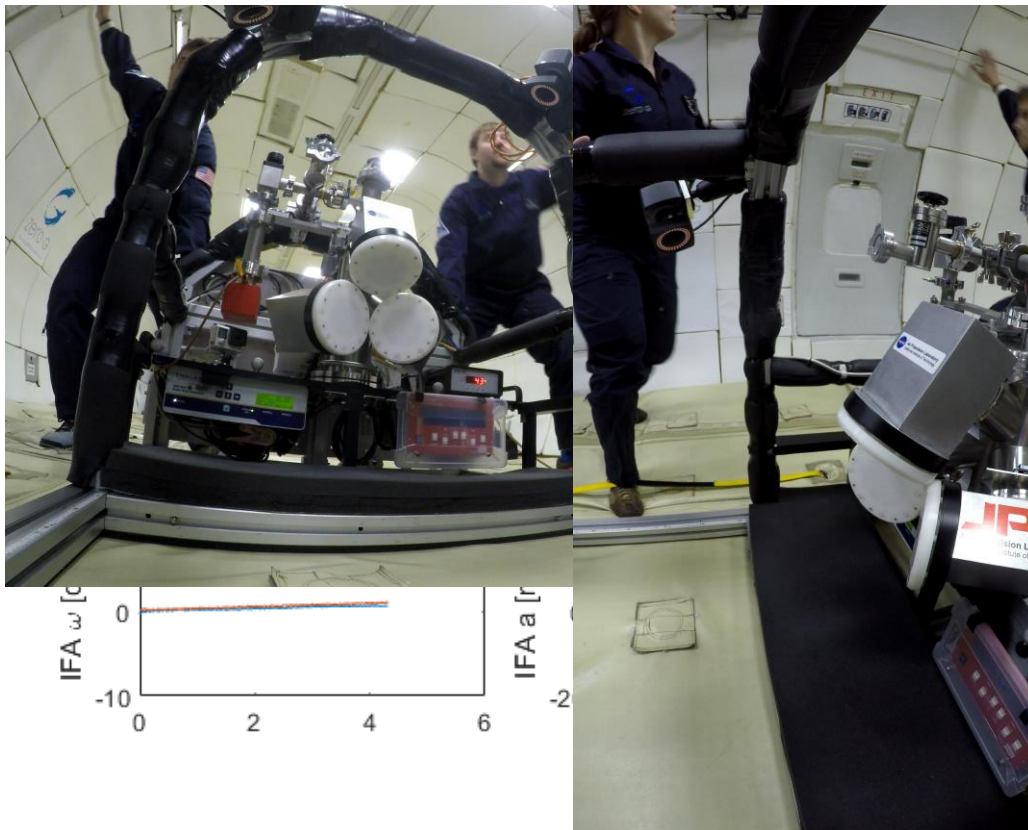
- EQ with no contacts
- No Vicon data, hard to back out global position and orientation
- Seems like an external influence on OSA at beginning of trial
- IFA angular velocity steady, inertial environment



Sample Tests and Interpretation



- Interesting capture test, contact
- Not enough time to settle/oscillations to damp out but very securely captured!





Things I need to move forward



- Frame IMU mounting orientation to subtract out of OSA IMU measurements
- OSA EQ wrt SROA pos for Vicon
- Location of Vicon marker on OSA wrt OSA CoM
- OSA center of mass, inertia, total mass
- Computer vision algorithms to back out OSA position and orientation when Vicon failed (also to verify Vicon)

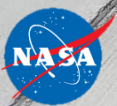


Assessments and Next Steps



zero G
the weightless experience

JPL
Jet Propulsion Laboratory
California Institute of Technology





Assessment



Things that Worked Well

- TRR and RPP Content
- Shipping/Travel/Hangar Work
- SROA Cooling
 - Switch to Aircraft Power Worked Well
 - Remote Monitoring of Cooling State Calmed Paranoia
- Frame as a Concept
 - GoPros
 - Tether
- Operational Concept
 - OS and Frame Control
 - Operational Awareness
 - Number of Experimenters
 - Amount of Space on the Aircraft
 - Remote Desktop
 - Having a Separate, Professional Photographer
- Pinning Equilibrium

Things that Did Not Go So Well

- Medication Effectiveness
- Sensing Issues
 - OSA Panels and Interaction with Vicon
 - IA/Hand Interference with Vicon
 - IMU Dropouts?
- Some Design Issues
 - Adjustable HW Needs Modification
 - Field Cooling Devices
 - OSA Switch
 - OS Going Under Frame
 - Magnet Strength vs. Disturbance Env.
- Length of Free-Float/Quality of Parabolas
- Capture
- Mistakes
 - Battery Charging for GoPros and Laptops
 - Magnet Dipole Direction



Progress Against Milestones in Last 6 Months

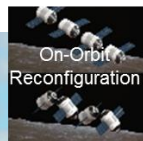
Plan	Actual	Milestone	Progress
Oct 2016	Aug 2016	Transfer MOSR hardware to FPOS project	Complete
Oct 2016	Oct 2016	Kickoff meeting	Complete
Oct 2016	Oct 2016	Experiment plan developed	Complete
Jan 2017	Dec 2016	Mid-year review	Complete
Spring 2017	Feb 2107	Hardware modifications and MOSR-FPOS interfacing complete	Complete
Spring 2017	Feb 2017	Successful end-to-end test	Complete
Spring 2017	Feb 2016	Operational dry-runs of experiments	Complete
Spring 2017	Dec 2016, Jan 2017, Feb 2017, Mar 2017	Draft of Research Program Package Draft to Armstrong Preliminary to Armstrong Final to Armstrong Final to Zero-G	Complete
Spring 2017	Jan 2017	Internal Test Readiness Review and Demonstration	Complete
Mar 2017 Two Microgravity Flight Days (Complete!)			
June 2017		Preliminary analysis report	In progress
July 2017		Dynamic modeling update peer review	Scheduled
Sept 2017		End of year report to Mars Exploration Directorate and JPL community	Not started yet



Plans for Next Year and Beyond



Autonomous
Rendezvous
and Docking



On-Orbit
Reconfiguration



Non-
Contacting
Grapple



Formation
Flying/
On-Orbit
Assembly



Isolated
Pointing
Platforms

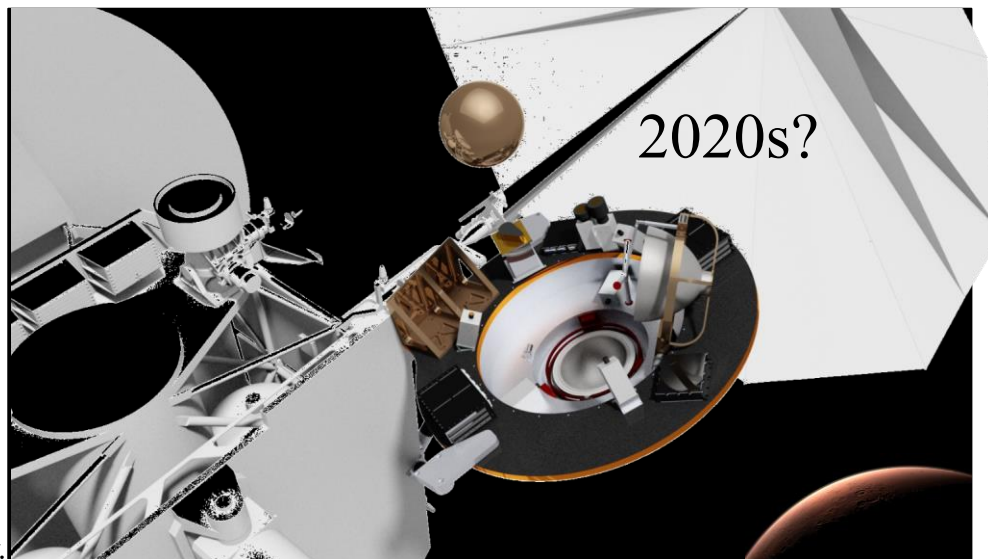


Nov 2017



2019?

logy.



2020s?